The Effects of a Mindfulness Meditation Training Intervention on Emotional Stroop Performance and Emotion Regulation

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Statement of Sources

I declare that this thesis is my own original work and that contributions of others have been duly acknowledged.

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Abstract

Mindfulness is a metacognitive skill that is suggested to have salutary effects on attentional control and emotion regulation. To examine this, the current study assessed the effects of one week of neurofeedback-based mindfulness training on emotion regulation and emotional interference. Twenty-two females and 11 males aged 20-24 years were recruited and randomly allocated to a mindfulness or relaxation control condition. Participants completed questionnaire measures of wellbeing and emotion regulation and an emotional Stroop task (ES task) to assess emotional interference. On the ES task, participants responded faster to congruent relative to neutral (p=.003) and negative words (p<.001), although there was no difference between negative and neutral words (p=.327), indicating the absence of an emotional Stroop effect. The hypothesised reduction in emotional interference and improved emotion regulation for the mindfulness condition was not supported. Predicted improvements in measures of wellbeing were also not found. Limitations, implications, and recommendations for future research are discussed.

Mindfulness meditation is the practice of cultivating and refining one's attentional focus by attending to the present moment in a non-judgemental and accepting manner (Kabat-Zinn, 2003). It is a metacognitive practice with roots originating in Eastern Buddhist traditions but has been increasingly researched and implemented in the West for its salutary effects on health and wellbeing. In particular, mindfulness has been shown to improve emotion regulation and executive attention. Gratz and Roemer (2004) define emotion regulation as the ability to monitor, accept, and understand one's emotions and engage in goal-directed behaviour even when emotionally stimulated. Emotion regulation abilities are facilitated by executive attention, which concerns the extent to which individuals can adaptively regulate their thoughts, emotions, and behaviours (Posner & Rothbart, 2009). In the current study, we aimed to investigate the effects of a mindfulness meditation training intervention on these domains using the emotional Stroop task (ES task) and the State Difficulties with Emotion Regulation Scale (S-DERS; Lavender, Tull, DiLillo, Messman-Moore, & Gratz, 2017).

The Buddhist tradition teaches that the human condition is characterised by physical and psychological suffering. Humans suffer psychologically because they cling to pleasant and unpleasant experiences and perceive them as true representations of reality (Hölzel et al., 2011). Framed in Western psychological terminology, we are bound by habitual emotional reactions. For example, we may react to the feeling of anger with violent words or actions, harming both ourselves and others. Likewise, the desire to be invariably happy causes us to suffer because such a continuous state is unattainable; our emotions are in a constant flux. According to Buddhist perspectives, we react to our emotions and feelings in such a way because we personally identify with them. As such, increased metacognitive awareness is necessary to understand the true nature of our emotions, and this can be achieved through mindfulness meditation training (Ekman, Davidson, Ricard, & Alan Wallace, 2005; Teasdale et al., 2002).

Two facets that are central to mindfulness meditation include an awareness of present moment experience and non-judgemental acceptance of thoughts, emotions and feelings (Teper, Segal, & Inzlicht, 2013). Awareness of the present moment is cultivated through decentration, or “standing back” from these mental events, and observing them as transient and subjective rather than reacting to or identifying with them (Bishop et al.., 2004; Lomas, Edginton, Cartwright, & Ridge, 2015). Once these mental events are non-judgementally observed and accepted, the attentional focus is returned to an object such as the breath (Bhayee et al., 2016). With practice, this ability to re-orient one’s attention and inhibit distracting stimuli is cultivated, resulting in improved executive attention, cognitive flexibility, and emotion regulation.

Executive Functioning and Emotion Regulation

The executive attention network comprises one of the three attentional networks proposed by Petersen and Posner (2012) and concerns the extent to which individuals can adaptively regulate their thoughts, emotions and behaviours. During mindfulness meditation, attention is maintained on one’s present internal and external experiences (Hölzel et al., 2011). The executive attention network is activated when thoughts, feelings, and emotions arise in consciousness because they conflict with one’s goal of sustaining a mindful state. Emotion regulation processes are then activated, resulting in an inhibition of habitual response tendencies (Tang, Yang, Leve, & Harold, 2012). For example, whenever a mental event arises, rather than habitually reacting to and becoming fixated with them, they become objects of observation before the attention is returned to the object of focus such as the breath, thereby preventing further elaborative processing (Bishop et al., 2004). Additionally, since attention has a limited capacity (Posner, 1978), inhibiting elaborative processing of irrelevant stimuli results in greater attentional resources available to process information in the present moment (Bishop et al., 2004). As such, mindfulness is thought to reduce interference of emotional stimuli and enhance cognitive flexibility. One method of assessing the influence of mindfulness on inteference of emotional stimuli is with the EST (Williams, Mathews, & MacLeod, 1996).

The Stroop Task

The Stroop task is one of the most commonly used measures of executive attention and cognitive flexibility (Macleod, 1991). The task assesses the extent to which individuals can suppress interfering information and re-direct their attention towards the task requirements (Moore & Malinowski, 2009). Specifically, it examines the extent to which automatic processes interfere with cognitively controlled processes. During the task, participants are asked to identify the ink colour in which a word is presented while ignoring the word itself. Since reading is considered an automatic process that is acquired through considerable practice over the lifetime of literate adults (Moore & Malinowski, 2009), this task requires considerable cognitive flexibility to overcome the habitual response tendency of reading the word. As such, individuals with less cognitive flexibility will typically take longer to respond to name the ink colour of an incongruent word (e.g. the word blue is printed in red ink) relative to a congruent word (e.g. the word blue is printed in blue ink) (de Ruiter & Brosschot, 1994). This increased RT is termed the “Stroop interference effect", which represents an inability to suppress habitual patterns of responding. Since mindfulness meditation is known to enhance cognitive flexibility and reduce habitual patterns of thinking and behaving, improved performance on the Stroop task following mindfulness practice would be expected (Moore & Malinowski, 2009).

The Emotional Stroop Task

The ES task is a variant of the traditional Stroop task that may be of particular interest in the study of mindfulness. The task examines the extent to which emotional processing of negative words or images causes task interference. The emotional interference effect occurs when individuals take longer to identify the colour of emotional/threatening words relative to neutral words, due to slowing of cognitive processing as a result of re-directing cognitive resources to processing the emotion-activating information (Watier & Dubois, 2016). As such, it is a useful measure of executive attention, specifically conflict monitoring, based on the extent to which emotional stimuli interfere with cognitive processing (McKenna & Sharma, 1995). The emotional interference effect is said to be pronounced in anxiety-prone individuals as a result of their attentional bias toward threatening stimuli (Lee & Orsillo, 2014). This is in line with Attentional Control Theory (Eysenck, Derakshan, Santos, & Calvo, 2007), which suggests that anxiety increases the allocation of attentional resources to threat-related stimuli, thereby reducing attentional focus on the present task. As such, research suggests that detection of emotional interference in healthy populations is limited (Malinowski, Moore, Mead, & Gruber, 2017). Nevertheless, others have found effects in healthy populations (Feng et al., 2018) and reductions in interreference following meditation interventions (Ortner et al., 2007). Furthermore, given that mindfulness has been shown to reduce anxiety (Zeidan, Johnson, Diamond, David, & Goolkasian, 2010) and is characterised by enhanced attentional control, non-reactivity to one's thoughts and emotions, and inhibition of elaborate processing of stimuli, mindfulness training should reduce the emotional interference effect.

Stroop Performance in Experienced Meditators

A review of the literature presents conflicting findings regarding the relationship between meditation experience and executive attention as measured by the Stroop task. Moore and Malinowski (2009) compared a group of experienced (n=25) and non-meditators (n=25) on a Stroop task. Mindfulness was measured with the Kentucky Inventory of Mindfulness Skills (KIMS) (Baer, Smith, & Allen, 2004) and the Stroop task was a paper-pencil version. Meditators were recruited from a local Buddhist centre and had completed at least a 6-week beginner's meditation course. Results revealed that meditators performed demonstrably better than non-meditators on the Stroop task, suggesting that automatic cognitive processes (i.e. reading) can be cognitively controlled with practice. However, there are several issues with the task administration that limit its reliable interpretation and comparison between studies. Firstly, the method by which they calculated interference is not typical for the Stroop task, which makes comparison among studies challenging. Furthermore, the task was a pen and paper version in which participants spoke the ink colour of the word aloud. Compared with a computerised task, this method of task administration is subject to measurement error (Strauss, Allen, Jorgensen, & Cramer, 2005). This error can be minimised by utilising computer presentation of stimuli and ensuring a highly accurate recording of response time (Strauss et al., 2005).

In contrast, Josefsson and Broberg (2011) found no differences on Stroop interference between mediators and non-meditators. They suggested that the refined attentional abilities gained from mindfulness meditation may not translate to enhanced performance on attention tests. While this may be true, their study also had several limitations that may explain the null findings. Firstly, Stroop interference was calculated using difference scores by subtracting the average reaction time for neutral and congruent words from incongruent words – a method that is commonly used though not recommended as it has been shown to possess low test-retest reliability and results in an accumulation of error (Eide et al., 2002; Strauss et al., 2005). Moreover, the meditating group consisted of older individuals from Buddhist centres and meditation groups (M_{age}=44 years), whereas the non-meditating group consisted of university students (M_{age}=26 years). The latter demographic is typically exposed to concentration and focus demands via university studies, potentially resulting in an enhanced ability to inhibit conflicting information. They are also likely to have higher computer proficiency having mostly grown up with technology, which may explain their faster RT on the computerised task. Additionally, by definition, a cross-sectional design cannot infer causation (Allen et al., 2012) and a sample of experienced meditators is not likely to be representative of the population of whom which the mindfulness training would benefit (Jensen, Vangkilde, Frokjaer, & Hasselbalch, 2012). As such, a training design with an active control group will help to control for these effects.

Stroop Performance in Mindfulness Interventions

Unlike cross-sectional designs, longitudinal designs have the benefit of monitoring changes within individuals over time and evaluating treatment outcomes (Anstey & Hofer, 2004). Current literature employing longitudinal designs in their investigation of mindfulness training on executive attention and wellbeing is conflicting. Bhayee et al. (2016) investigated the effects of 6 weeks of daily (10 mins) neurofeedback-assisted, technology supported mindfulness training (N-tsMT) on attention and wellbeing. N-tsMT involves detection of brain activity, which is relayed to the participant in real-time. Participants then engage in attentional training by modulating their brain activity in response to the neurofeedback (Bhayee et al., 2016). In this study, N-tsMT was delivered using Interaxon's Muse^{TM}, a wireless EEG headset that detects brain signals via electroencephalography, and an accompanying mobile phone application. Relative to an active online maths game control condition, the N-tsMT condition showed decreased RT to congruent and incongruent stimuli, although there was no reduced interference on the Stroop task. They explained that the N-tsMT may produce a weaker effect relative to more rigorous meditation training. Another limitation was their inability to distinguish whether the findings were a consequence of the neurofeedback, training effects, or expectancy effects. Having a training expectancy measure may overcome these limitations. Additionally, they found that positive effects of mindfulness were largest in individuals high in neuroticism. As such, they outline that the ability to find clinically meaningful effect sizes in a healthy population may be limited. Nonetheless, they found that attention and wellbeing improvements were correlated.

On the contrary, Wenk-Sormaz (2005) found that a brief meditation intervention significantly reduced Stroop interference. They compared transcendental meditation (Coffey, Hartman, & Fredrickson) with a learning and a rest/mind-wandering control condition. TM is a form of meditation that involves focused attention on a word or mantra such as "om" while disregarding any thoughts or feelings that may arise (Wenk-Sormaz, 2005). All conditions involved three 20-

minute sessions within a 2-week timeframe. Since cognitive effects due to mindfulness may be mediated by physiological relaxation, the researchers controlled for this by measuring galvanic skin response (GSR). They performed planned contrasts to assess between-group differences and then added arousal percent difference (APD) as a covariate. In line with their hypotheses, the participants in the TM session demonstrated reduced Stroop interference. They also found a reduction in arousal following meditation, although this reduction in arousal did not account for the improved Stroop performance. These results suggest that even brief exposure to meditation can reduce habitual responding.

Mindfulness Training Interventions and Emotional Stroop

Ortner, Kilner and Zelazo (2007) examined the extent to which a 7-week mindfulness intervention influenced emotional reactivity relative to a body awareness and relaxation and a waitlist control condition. Relaxation was used as a control because some of the beneficial effects of mindfulness may be partially due to relaxation and controlling for this will partial out these effects. Indeed, while both mindfulness and relaxation have been shown to reduce anxiety, they do so through unique mechanisms and are associated with distinct EEG patterns (Fan, Tang, Tang, & Posner, 2014). Emotional reactivity was examined using the emotional interference task (EIT) (Buodo, Sarlo, & Palomba, 2002) which involves judging whether a tone is low- or high-pitched while being presented with neutral, pleasant or unpleasant pictures. Like the ES task, participants are usually slower to respond to the tone when observing unpleasant stimuli due to the increased attentional resources required to process the emotional information. In line with their predictions, only the mindfulness condition showed reduced emotional interference to unpleasant stimuli on the EIT, which may suggest that they were more successful in inhibiting elaborative processing of negative information.

Allen et al. (2012) compared BOLD (blood oxygenation level-dependent) signals of a mindfulness and reading control group during an affective Stroop task. Participants completed the experimental sessions before and after 6 weeks of their intervention. The task involved a number-counting Stroop task with negative, positive or neutral images from the International Affective Picture System (IAPS). Congruent trials were those in which the numbers were consistent with numerosity (e.g. four “4”s) and incongruent trials were those in which they were inconsistent (e.g. three “4”s). The authors predicted that IAPS images would interfere with task performance due to bottom-up affective processing and use of additional cognitive resources. However, results showed no mean behavioural differences between groups. Nonetheless, they found that adherence to meditation practice strongly predicted activation of brain regions involved in bottom-up salience, awareness, and cognitive control when processing the negative stimuli.

Brief Mindfulness Intervention and Emotional Stroop

Lee and Orsillo (2014) compared a mindfulness with a relaxation and a thought-wandering control condition on the emotional Stroop task. They were particularly interested in whether effects are pronounced in individuals with general anxiety disorder (Jensen et al., 2012). Those in the mindfulness condition listened to an audio recording aimed at focused attention to breath, the relaxation condition relaxed as they listened to music, and the thought-wandering condition listened to an audio recording that instructed them to sit quietly and think of whatever comes to mind. All manipulations lasted 20 minutes. They found that the emotional Stroop effect was observed in individuals with elevated GAD symptoms. Additionally, as predicted, they found that individuals with elevated GAD symptoms demonstrated a reduced emotional interference effect following mindfulness and relaxation manipulations relative to the thought-wandering manipulation. However, contrary to their predictions, there were no overall differences between the mindfulness and relaxation condition in emotional Stroop performance. They explained that this may be because they were unsuccessful in clearly distinguishing mindfulness from relaxation in their manipulation. For example, since the relaxation condition were instructed to pay attention to the music recording, this attentional focus may have played a role in enhancing cognitive flexibility.

Mindfulness and Emotion Regulation

The literature highlights an important link between executive functioning and emotion regulation, at both the cognitive (Broderick & Metz, 2009) and neural level (Goldin & Gross, 2010; Modinos, Ormel, & Aleman, 2010). Coffey et al. (2010) explored the common underlying features of mindfulness and emotion regulation using a path analysis on 413 participants with little to no meditation experience. Between the Five-Factor Mindfulness Questionnaire (FFMQ; Baer et al., 2006) and the Difficulties with Emotion Regulation Scale (DERS; (Gratz & Roemer, 2004), they found that two central facets of mindfulness, present-centred attention and acceptance of internal experience, enhanced clarity about one’s internal experience, which in turn contributed to the ability to manage negative emotions. However, this study investigated dispositional mindfulness and was therefore correlational, whereas an intervention design would produce stronger results.

Broderick and Metz (2009) utilised an intervention design in their investigation of the effects of a mindfulness curriculum on emotion regulation in an adolescent classroom setting. The experimental condition included 104 females in

Grade 12 (m_{age}=17.4 years) and the control condition included 17 females in Grade 11 (m_{age}=16.4 years). Program sessions were delivered approximately twice per week over 7 weeks during Health classes, each session ranging from 32 to 43 minutes. Results demonstrated the mindfulness curriculum was successful in improving emotion regulation abilities. However, having a different age group as the control condition has clear limitations such as maturation effects or other stressors relevant to being in their final year. A randomised design may overcome these limitations.

Neuroimaging studies also highlight the key relationship between mindfulness, executive functioning, and emotion regulation. Modinos et al. (2010) conducted a functional MRI (fMRI) study on meditation-naïve participants. They found that while participants were attending to negative stimuli, dorsomedial prefrontal activation simultaneously increased with dispositional mindfulness traits. In particular, this simultaneous activation was inversely correlated with amygdala activation in response to negative scenes, providing evidence that mindfulness downregulates emotion-related brain regions through executive functions. Goldin and Gross (2010) found similar patterns of brain activation, coupled with reductions in negative emotion experience and enhanced emotion regulation, following a two-month Mindfulness-Based Stress Reduction (MBSR) program in participants with Social Anxiety Disorder. However, this study did not use a randomised control group and was therefore subject to practice effects and habituation to the fMRI scanner environment. Additionally, they did not include any self-report mindfulness measures to determine the effectiveness of the MBSR intervention on levels of mindfulness. Nonetheless, these studies provide evidence for a clear link between mindfulness and emotion regulation. This may be because mindfulness enhances metacognition of emotional states, and understanding the transitory nature of emotions facilitates the ability to remain goal-directed when emotionally activated (Goodall, Trejnowska, & Darling, 2012).

Rationale, Aim, and Hypotheses

Overall, the literature provides evidence that attention and emotion regulation are cultivated through mindfulness meditation at the cognitive and neurological level. However, there are some discrepancies within the literature, which may be due to methodological inconsistencies and design limitations such as calculating interference with difference scores rather than response latencies, lacking a randomised control condition, using a cross-sectional design, and not accounting for the effects of relaxation or expectancy. Furthermore, the literature presents a considerable lack of consistency in emotional Stroop task methodology, which makes comparison of studies challenging. Variations include response type (verbal; finger-press), word type (emotional; neutral; and/or positive), stimulus presentation (computerised; word-card), ink colours, stimulus (words; pictures; noises), neutral and emotional words used, and the number of trials.

The current study involved computer presentation of stimuli, highly accurate recording of response time, use of standardised stimuli, and inclusion of practice trials to reduce measurement error (Strauss et al., 2005). Further, we included an active relaxation control condition and expectancy measure. Additionally, Crivelli, Fronda, Venturella, and Balconi (2019) suggest that the use of an external device such as the Muse™ may strengthen attentional effects via neurofeedback. To the best of our knowledge, there are no peer-reviewed studies investigating the effects of neurofeedback-based mindfulness intervention on emotional Stroop performance. As such, we will implement mindfulness and relaxation via neurofeedback-based devices, which has the added benefit of providing an objective measure of training adherence.

Research on the underlying mechanisms of mindfulness is still in its infancy. Therefore, a better understanding of these mechanisms in healthy participants may contribute to the emerging field of positive psychology and have significant real-world implications. For example, it may reduce the intensity and unpleasantness of negative emotions, rumination, anxiety, and stress, and improve overall wellbeing and attention. The current study aimed to fill the research gap by investigating the impact of a neurofeedback-based mindfulness meditation training intervention on executive attention and emotion regulation as measured by the emotional Stroop task and the State Difficulties with Emotion Regulation Scale (S-DERS). A randomised active relaxation control condition was used to distinguish the effects of focused attention to breath from relaxation alone. Additionally, a Training Outcome Questionnaire was used to assess task expectancy.

Considering the theoretical link between executive attention and emotion regulation, it was predicted that mindfulness training would result in reductions in emotional Stroop interference and difficulties with emotion regulation. Specifically, it was hypothesised that compared with pre-intervention, at post-intervention the mindfulness group would slow decreased reaction times when responding to negative words relative to neutral words. It was further hypothesised that these reaction time reductions would be larger for the mindfulness than the relaxation control group. Lastly, it was hypothesised that mindfulness training would result in reductions in difficulties with emotion regulation relative to the control group.

Method

Participants

An a priori power calculation (G-Power 3.1.9.2) indicated that a sample size of 40 would be adequate to detect a moderate effect size (f=0.25) with a power of 0.8 at α=.05. Participants were recruited via advertisements placed around the university campus and on social media, word-of-mouth, and an online research participation portal. The final sample consisted of 22 females (11 males) aged 20-24 years (M_{age}=22.42, SD=2.89) randomly allocated to a mindfulness (n=15) or relaxation control group (n=18). As reimbursement for time and travel costs, participants received a $60 gift voucher or 4 hours of research participation credit and a $20 voucher.

Exclusion criteria included previous meditation/relaxation experience (in the last year or more than 5 hours lifetime), colour-blindness, history of psychiatric or neurological disorders (including epilepsy), severe head injury, seizures, giddiness or loss of consciousness (>2 mins), a heart condition or any other serious physical condition, current daily tobacco use, regular illicit drug use, problematic alcohol use (scores >16 on the Alcohol Use and Disorders Identification Test (AUDIT; Babor et al., 2001), high psychological distress (scores >30 on the Kessler Psychological Distress scale (K10; Kessler et al., 2002), current use of prescription medications (excluding the contraceptive pill), current sleep disorders, uncorrected hearing or vision problems, pregnancy, and first languages other than English. This research was approved by the University of Tasmania Human Research Ethics Committee (see Appendix E).

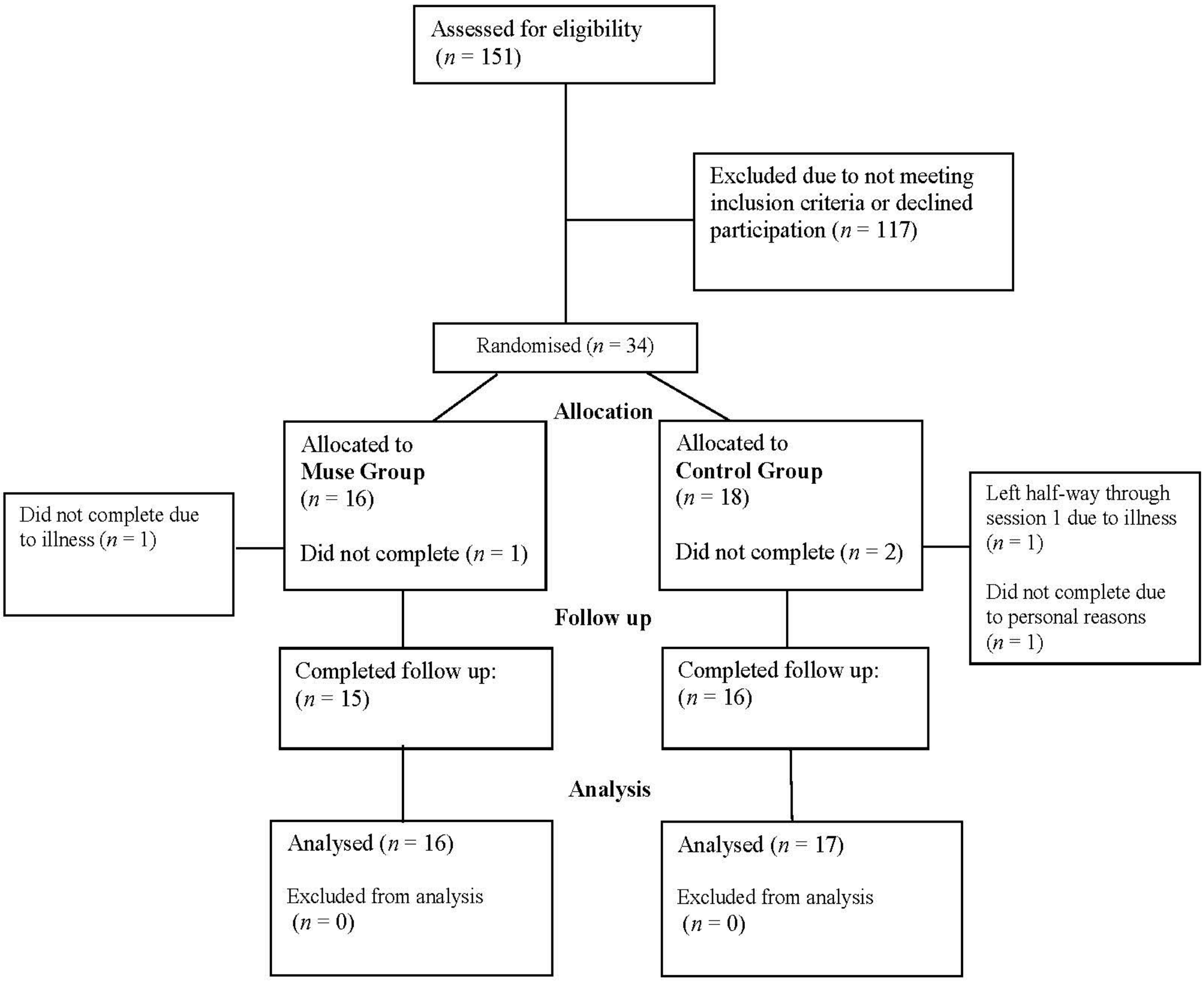

Figure 1. CONSORT diagram of the study participants

Materials

Screening measures. Participant's demographic information, health status, meditation and relaxation history, video gaming experience, substance use history, current alcohol use (AUDIT), and psychological distress (K10) were obtained in an online screening questionnaire (see Appendix X).

AUDIT. The AUDIT is a valid and reliable 10-item measure assessing alcohol misuse and other alcohol-related problems (Reinert & Allen, 2007). Items are summed with higher scores indicating higher severity in alcohol-related problems.

K10. The K10 is a 5-point Likert-type scale ranging from 'none of the time' to 'all of the time'. The maximum score is 50, indicating severe distress, and the minimum score is 10, indicating no distress (Andrews & Slade, 2001).

Control measures. We assessed equivalence of groups on various control variables to eliminate potential confounds. Participant's baseline trait anxiety (State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), trait mindfulness (Five-Facet Mindfulness Questionnaire (FFMQ-15; Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006), personality traits (Mini International Personality Item Pool (IPIP; (Donnellan, Oswald, Baird, & Lucas, 2006), and training expectancy was assessed (see Appendix B). We also assessed participants on verbal intelligence using the Wechsler Test of Adult Reading (WTAR; Weschler, 2001). The Karolinska Sleepiness Scale (KSS; Åkerstedt & Gillberg, 1990) was used to assess equivalence of groups pre- and post-intervention on current fatigue. A Rating Scale for Word Valence and Arousal (Lee & Orsillo, 2014) was used to ensure equivalence of stimulus characteristics between word valence conditions for the ES task.

STAI (T-Anxiety). The STAI is a measure of state and trait anxiety that possesses sufficient internal consistency and test-retest reliability (Barnes, Harp, & Jung, 2002). The measure comprises two subscales; the State Anxiety Scale (S-Anxiety) and the Trait Anxiety Scale (T-Anxiety). The T-Anxiety Scale assesses individual differences in the intensity and frequency of stable anxiety characteristics (Julian, 2011).

FFMQ. The FFMQ-15 is a shorter version of the original 39-item FFMQ. Items are rated on a 5-point Likert-type scale ranging from 'rarely or very rarely true' to ‘very often or always true’. It possesses adequate internal consistency and sufficient convergent validity with the original measure (Gu et al., 2016).

Mini-IPIP. The Mini IPIP is a 20-item short form assessing the Big Five factors of personality. Previous literature suggests that the effectiveness of mindfulness training can vary depending on personality factors such as Neuroticism (Bhayee et al., 2016). Consistent and acceptable reliability and validity of the Mini IPIP has been demonstrated (Donellan et al., 2006).

WTAR. The WTAR assesses verbal intelligence based on correct pronunciation of 50 irregularly spelled words. Each correctly pronounced word received a one score and raw scores were summed to provide an overall indication of intelligence.

Training Outcome Questionnaire. The Training Outcome Questionnaire comprises three questions on a 9-point Likert scale ranging from ‘Not at all’ to ‘Very much’, with higher scores indicating larger task expectancy. Only the last question relating to expected improvements in emotional wellbeing was analysed in the current study.

KSS. The KSS is a subjective measure of current fatigue. The 9-point scale ranges from ‘Extremely alert’ to ‘Very sleepy, great effort to keep awake, fighting sleep’, with higher scores representing greater fatigue.

VARS. Each word in the ES task was rated on a 9-item Likert scale for pleasantness, ranging from ‘Extremely unpleasant’ to ‘Extremely pleasant’ and arousal from ‘Low arousal’ to ‘High arousal’.

Outcome measures. State mindfulness, emotion regulation, state anxiety, and current mood and fatigue were assessed with the Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003) and Cognitive and Affective Mindfulness

Scale-Revised (CAMS-R; Feldman, Hayes, Kumar, Greeson, & Laurenceau, 2007), the State Difficulties with Emotional Regulation Scale (S-DERS; Lavender et al., 2017), the STAI (S-Anxiety) the Profile of Mood States Questionnaire Short-Form (POMS-SF; Shacham, 1983).

MAAS. The MAAS is a 15-item questionnaire measuring the extent to which respondents are openly attentive to and aware of the present moment experience. Items are rated on a 6-point Likert scale from ‘almost always’ to ‘almost never’.

CAMS-R. This is a 12-item scale with higher scores indicating higher levels of mindfulness. The measure is designed to encompass a broad conceptualisation of mindfulness (Feldman et al., 2007). Sample items include, “I can tolerate emotional pain” and “I try to notice my thoughts without judging them”.

S-DERS. The S-DERS is a modified version of the original DERS designed to assess state levels of emotion dysregulation. Four subscales within the S-DERS include Nonacceptance of Current Emotions, Limited Ability to Modulate Current Emotional and Behavioral Responses, Lack of Awareness of Current Emotions, and Lack of Clarity about Current Emotions. Participants were asked to indicate how much each item applies to them ‘right now’ on a 5-point Likert scale ranging from ‘not at all’ to ‘completely’. The measure has been shown to possess good internal consistency (Lavender et al., 2017).

STAI (S-Anxiety). This scale assesses how participants feel ‘right now’ in terms of activation of tension, apprehension, worry, and nervousness (Julian, 2011).

The POMS-SF. This scale comprises a list of 37 adjectives. Participants indicate the extent to which the adjective currently describes them on a 5-point Likert scale. The short-form has comparable internal consistency estimates with the original POMS (Curran, Andrykowski, & Studts, 1995).

Emotional Stroop Task (ES Task; Williams et al., 1996). The ES task assesses the extent to which emotional stimuli interfere with cognitive processing. The task was presented on a PC using STIM^2 software with stimuli presented in size 48, Arial font. Fifteen negative and 15 neutral words were adapted from McKenna and Sharma's (1995) word-bank and were matched in frequency and length (see Appendix C). The task also included a colour-congruent block of words (e.g. the word "blue" presented in blue ink) as an additional control variable and a comparator to the neutral and emotional word condition. Words were presented in either green, red, blue, or yellow.

Within each trial, a fixation cross was presented in the centre of the screen for 500ms, followed by a word which was presented for 1000ms or until a response was made. A black screen was then presented for a 1000-15000ms inter-trial interval. Participants completed 10 trials of letter strings (e.g. XXXX) to familiarise themselves with the task. There were 180 experimental trials (15 words x 4 colours x 3 word-types) that were blocked according to word-type, with participants completing 60 congruent, 60 neutral and 60 negative trials. The congruent trial was always presented first but the order of negative and neutral trials was counterbalanced between participants. The word-type/font-colour combination was randomised with the exception that the same word or font-colour did not appear in consecutive trials. Response time for each trial was measured from stimulus onset to the key press.

Interventions

The Muse™ (InteraXon Inc., Toronto, ON, Canada; SCR_014418). The Muse™ is a portable electroencephalographic (EEG) system that uses neurofeedback as a mindfulness training tool. The Muse comprises a wireless EEG headband with seven brain sensors and an accompanying mobile phone application. At the start of the session, participants underwent initial calibration of the Muse device to ensure a clear signal of their brain activity. During calibration, participants were instructed to manually adjust the headband to fill each of the four sections of a circle with colour, with one colour representing each sensor. Each coloured section indicates brain signal strength and required filling before participants could continue. Following calibration, participants completed another one-minute calibration session to establish their baseline for receiving auditory feedback.

During the mindfulness training sessions, participants received auditory neurofeedback in the form of weather sounds. Highly active brain signals resulted in stormier weather noises and less active signals resulted in calmer weather noises. The aim of the mindfulness practice was to calm weather noises by focusing their attention to their breath. Participants completed ten courses within the "Muse Essentials" option for 20 minutes per day for 7 days.

The Pip (Pip® Galvanic Ltd, Ireland). The Pip was used in the relaxation control condition. The Pip is a biofeedback device that is held between the thumb and forefinger and measures the galvanic skin response (GSR), which is suggested to be a reliable method of measuring sympathetic medullary system activity – a system that is involved in the stress response (Dillon, Kelly, Robertson, & Robertson, 2016). The Pip sensors detect electrodermal activity in the fingertips eight times per second (Dillon et al., 2016). This activity is classified as 'stressed', 'relaxed', or 'constant', depending on whether it detects increases or decreases (Hollis, Pekurovsky, Wu, & Whittaker, 2018). This information is transmitted via Bluetooth to the mobile phone application, where algorithms analyse the electrodermal activity and determine progress in a stress-reduction game.

The Pip's 'The Loom' was used in the current study. The Loom is a game involving visual imagery, in which the participant is presented with a nature scene that progresses as they become more relaxed. The three scenes were 'New Life', 'Awaken', and 'Enchanted Forest'. For example, within 'New Life' participants progressed from a winter to a summer scene by reducing their stress levels. The more relaxed they were, based on reductions in skin conductance response, the faster the progression. Permission for use of the Muse and Pip devices was granted by the developers.

Procedure

Participants were screened online using the screening questionnaire. Following screening, eligible participants were randomly allocated to the mindfulness or control condition and were invited to attend two experimental sessions at the University of Tasmania. Upon arrival, participants read and signed an informed consent sheet. Participants were then seated at a computer and completed the experimental session screening questionnaire (assessing substance use including medications, tobacco, alcohol, coffee, and illicit drugs in the period prior to testing) to confirm eligibility to participate. Participants then completed the outcome questionnaire measures including the MAAS, CAMS-R, S-DERS, POMS-SF, STAI (S-Anxiety), and KSS. The WTAR was then completed face-to-face with the researcher.

Following EEG set-up participants were seated approximately 60cm in front of a computer screen and completed the Attentional Network Test (Eysenck et al., 2007) and the ES Task in counterbalanced order, followed by an EEG resting state task (the EEG and ANT data were analysed in separate studies). During the ES task, participants were instructed to make a key-response indicating the colour of the word presented on the screen as quickly and accurately as possible.

Following completion of the experimental tasks, the EEG cap was removed. Participants then received either Muse or Pip task instructions depending on whether they were assigned to the mindfulness or relaxation condition, respectively (see Appendix X). They had the choice to use their own mobile phone (if compatible) or an android phone provided by the researchers. Participants then completed a training expectancy measure (see Appendix X).

Participants were made aware of the potential risks involved with the Muse or Pip device such as discomfort and irritation. For those in the mindfulness condition, the researcher fitted the device on the participant's head, helped them download the Muse application, create an account, and connect the Muse. The 'Muse essentials' option was selected and participants began a new session involving instructions and calibration. The researcher showed participants in the relaxation condition how to use the Pip device and how to download the application. In both groups, participants were instructed to complete their practice in a quiet room where they would not be distracted with their back in an upright position that was maintained (if possible) throughout the session.

Both groups were instructed to complete approximately 20-minutes of training over 7 days. Participants were given the opportunity to ask questions. Following 7 days of their intervention, participants returned to the lab for post-training measures, including the experimental session screening questionnaire to confirm eligibility to participate, the questionnaire outcome measures (MAAS, CAMS-R, S-DERS, POMS, STAI-S), followed by EEG setup and the three experimental tasks (ANT, ES task, EEG resting state measure). Participants then rated the valence and arousal of emotional and neutral words from the ES task on a computer (VARS). Participants then reported their training adherence based on Muse and Pip application data and were given the opportunity to leave comments about their device (e.g. any issues they encountered). Participants were then debriefed and reimbursed.

Design and Data Analysis

Emotional interference is commonly calculated with difference scores, by subtracting the RT for neutral words from emotional words (e.g. Bhayee et al., 2016). However, this method has been shown to possess low test-retest reliability and results in an accumulation of measurement error (Eide et al., 2002; Strauss et al., 2005). Rather, calculating emotional interference with response latencies is suggested to be the superior method because it has higher test-retest reliability, suggesting the observed response times are consistent over time (Strauss et al., 2005). As such, behavioural dependent variables were emotional interference as measured by mean response latency for neutral and negative words, and t as measured by mean response latency for congruent and neutral words. Incorrect responses and responses less than 150ms or 3 SDs above the individual condition mean for each participant were excluded. While the main hypotheses were on reaction time, accuracy (% of correct trials) was also analysed to determine whether there was evidence for a speed-accuracy trade-off.

Assumptions for each test were assessed to ensure data was appropriate for the analyses. Data were analysed using IBM SPSS Version 24. Effects of mindfulness and relaxation training on ES task performance was assessed using a between-subjects 2(Group: mindfulness, relaxation) x 2(Time: pre, post) x 3(Condition: congruent, negative; neutral) mixed models analysis using the

Maximum Likelihood method. A comparison between Compound Symmetry and Unstructured covariance structures was conducted and the former was found to provide a significantly better fit of the data. Participants were included as random factors to account for individual error and missing data, resulting in higher power and more precise estimates (Detry & Ma, 2016). Mixed models analysis was chosen for its parsimony, considerable flexibility in experimental designs when data is hierarchical and nested, its ability to deal with missing data, and that it allows for violations of typical regression assumptions of independent error terms and equal variances (Garson, 2013). Accuracy was also analysed using mixed models with a Compound Symmetry covariance structure and the Maximum Likelihood method.

Univariate ANOVAs were used to assess equivalence of groups in age, sex, the AUDIT, K10, STAI(T-Anxiety), FFMQ-15, Mini-IPIP, WTAR, VARS, expectancy ratings, and training adherence (minutes). To examine differences between groups pre- and post-intervention on the MAAS, CAMS-R, S-DERS, POMS-SF, STAI(S-Anxiety) and KSS, 2 (Group: mindfulness, relaxation) x 2 (Time: pre, post) repeated measures ANOVAs were conducted.

Theoretically relevant significant ($p<.05$) or approaching significant main effects and interactions were followed up with analyses of simple main effects and post-hoc pairwise comparisons, with Bonferroni adjustments applied when necessary to keep the family-wise error rate at .05. Partial eta squared (η_p^2) represented effect sizes for interactions and was interpreted as 0.01=small, 0.06=medium, 0.14=large (Jacob Cohen, 1988). Hedge's *g* was applied for main effects and tests of simple effects and was interpreted as 0.2=small, 0.5=moderate, 0.8=large (J. Cohen, 1992).

Results

Screening and Control Variables

Table 1 displays descriptive statistics for control questionnaire measures for each group. Results revealed small and non-significant differences between mindfulness and relaxation groups on age, problematic alcohol use, psychological distress, trait anxiety, trait mindfulness, raw intelligence scores, current fatigue, training expectancy, and training adherence (minutes).

Outcome Questionnaire Measures

Descriptive statistics and effects of Time for outcome questionnaire measures for the relaxation and mindfulness groups are displayed in Table 2. Contrary to predictions, the Group x Time interactions for state mindfulness (MAAS), $F(1, 29)=1.28$, $p=.268$, $\eta_p^2=.042$ and (CAMS-R), $F(1, 29)=0.08$, $p=.780$, $\eta_p^2=.003$, current mood, $F(1, 29)=0.17$, $p=.681$, $\eta_p^2=.006$ were non-significant. The Group x Time interaction for state anxiety was non-significant, $F(1, 21)=2.05$, $p=.167$, $\eta_p^2=0.089$.

For the S-DERS, the main effect of Time was small and non-significant, with participants scoring lower post-intervention relative to pre-intervention, $F(1, 29)=3.93$, $p=.057$, $g=0.316$. The main effect of Group was small and non-significant, $F(1, 29)=0.46$, $p=.504$, $g=0.237$, and the hypothesised Group x Time interaction was small and non-significant, $F(1, 29)=0.07$, $p=.793$, $\eta_p^2=.002$ (see Figure 2). When groups were analysed separately, results revealed small and non-significant reductions in difficulties with emotion regulation post-intervention relative to pre-intervention for both groups. No other significant main effects or interactions were found for any of the other outcome measurers.

Table 1

Descriptive statistics for control questionnaire measures by Group

	Mindfulness			Relaxation					
Variable	n	*M (SD)*	95% CI *[LL, UL]*	n	*M (SD)*	95% CI *[LL, UL]*	*F*	*p*	*g*
Age	16	22.3(3.3)	[20.6,24.1]	17	22.5(2.6)	[21.2,23.8]	0.05	.495	0.235
Problematic Alcohol Use (AUDIT)	16	4.3(2.9)	[2.7,5.9]	17	3.7(2.6)	[2.3,5.0]	0.48	.495	0.235
Psychological Distress (K10)	15	15.2(4.4)	[12.8,17.6]	17	14.2(4.2)	[12.1,16.4]	0.41	.529	0.220
Trait Anxiety (STAI (T-Anxiety)	16	36.9(8.4)	[32.5,41.4]	17	38.3(8.0)	[34.2,42.4]	0.23	.637	0.161
Trait Mindfulness (FFMQ-15)	16	51.0(5.8)	[47.9,54.1]	17	47.7(8.2)	[43.4,51.9]	1.81	.188	0.458
Intelligence (WTAR raw score)	16	41.4(4.0)	[39.3,43.6]	17	42.0(5.3)	[39.2,44.7]	0.09	.761	0.104
Current Fatigue (KSS)	15	3.5(1.1)	[-1.2,0.4]	16	3.9(1.1)	[3.3,4.5]	1.01	.323	0.361
Training Expectancy (Training Outcome Questionnaire)	14	6.6(1.8)	[5.6,7.7]	16	7.9(1.2)	[6.7,8.1]	1.78	.193	0.480
Training Adherence (minutes)	14	127.9(28.7)	[111.3,144.4]	16	146.9(56.0)	[117.1,176.7]	1.31	.262	0.408

Note. CI = confidence interval; *LL* = lower limit; *UL* = upper limi

Table 2

Means, (SD), p-values and effect sizes for pre-post outcome questionnaires for Mindfulness and Relaxation groups

	Mindfulness				Relaxation			
	Pre-intervention	Post-intervention			Pre-intervention	Post-intervention		
Scales	*M(SD)*	*M(SD)*	*p*	*g*	*M (SD)*	*M (SD)*	*p*	*g*
State Emotion Regulation (S-DERS)	35.7(5.9)	33.2(6.5)	.061	0.385	36.9(7.6)	35.0(7.5)	.310	0.244
State Anxiety (STAI)	32.5(7.8)	32.5(6.1)	.907	0.012	31.3(8.3)	34.6(8.8)	.131	0.352
Current Mood (POMS-SF)	17.9(6.0)	18.3(7.3)	.965	0.047	22.0(13.1)	23.8(16.5)	.566	0.112
State Mindfulness (MAAS)	3.8(0.7)	3.7(0.7)	.729	0.109	3.6(1.0)	3.8(0.9)	.307	0.156
State Mindfulness (CAMS-R)	30.6(4.7)	32.1(4.2)	.187	0.130	29.5(4.4)	30.6(4.3)	.333	0.062

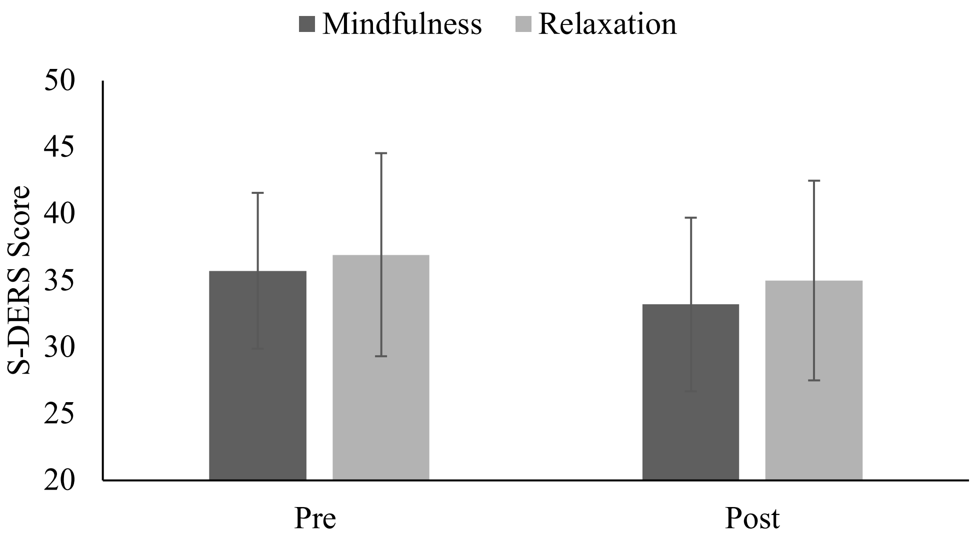

Figure 2. Mean state difficulties with emotion regulation before and after the mindfulness and relaxation interventions (error bars denote standard deviations).

Emotional Stroop task

Reaction Time (ms). A comparison of the model using Compound Symmetry (-2LL=2097.8, 14 parameters) and Unstructured (-2LL=2018.6, 33 parameters) covariance structures for repeated measures indicated that the model using Compound Symmetry provided a significantly better fit, $\chi^2_{change}(19)=79.34$, $p<.001$, and a decrease in BIC from 2191.44 to 2171.19. While the Compound Symmetry model has a larger -2LL value, it is more parsimonious, has more power, and has a lower BIC and was therefore used in the final analysis.

Table 3 displays the means and 95% confidence intervals for RT. The analysis revealed a significant main effect of Time, indicating that participants were significantly faster post-intervention, (M=539.85, 95%CI[523.9,555.9]) than pre-intervention (M=580.94, 95%CI[397,921.4]), $F(1, 158)=33.92$, $p<.001$. Partially supporting the hypotheses, there was a significant main effect of Condition, $F(1, 158)=8.84$, $p<.001$, with participants responding faster to congruent relative to neutral (*p*=.003, *g*=0.320) and negative words (*p*<.001, *g*=0.383). However, there was no significant difference between negative and neutral words (*p*=.327, *g*=0.099). The hypothesised Group x Time x Condition interaction was not significant, *F*(2, 156)=0.62, *p*=.541. There were no other significant main effects or interactions (see Figure 3 and Appendix H for *F* tests).

Table 3

Cell means (SD) for reaction time (ms) for all Condition, Group, and Time conditions

		Group			
		Mindfulness		Relaxation	
Time	Condition	*M (SD)*	95% CI *[LL, UL]*	*M (SD)*	95% CI *[LL, UL]*
Pre	Congruent	587.27(113.26)	[403.74,791.19]	552.10(96.07)	[397.00,723.26]
	Neutral	584.60(76.87)	[436.25,726.04]	584.61(91.29)	[439.79,754.90]
	Negative	584.28(93.40)	[404.33,777.75]	594.32(120.59)	[434.65,921.41]
Post	Congruent	516.99(64.44)	[413.49,648.00]	501.57(71.97)	[398.75,611.80]
	Neutral	548.33(71.52)	[436.93,436.93]	549.44(74.66)	[435.77,663.52]
	Negative	566.74(79.29)	[457.39,788.63]	556.83(556.83)	[408.61,746.17]

Note. CI = confidence interval; *LL* = lower limit; *UL* = upper limit

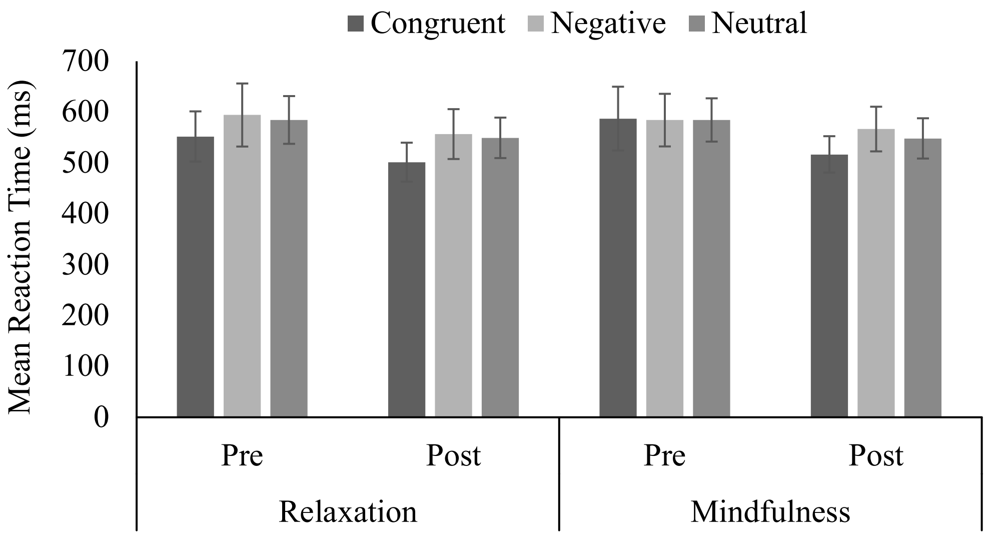

Figure 3. Mean reaction time (ms) for the emotional Stroop task in response to congruent, negative, and neutral valanced words, pre- and post- mindfulness and relaxation interventions (error bars denote 95% confidence intervals)

Accuracy (%). A comparison of the model using Compound Symmetry (2LL=1036.34, 14 parameters) and Unstructured (-2LL=1005.12, 33 parameters) covariance structures for repeated-measures revealed that the model using Compound Symmetry provides a significant improvement in model fit, $\chi^2_{change}(19)=31.22$, $p=.038$, and a decrease in BIC from 1177.92 to 1109.65. Interpretation was therefore based on the analysis using Compound Symmetry.

Table 5 displays the means and 95% confidence intervals for accuracy. The main effects of Group, $F(1, 32.91)=0.04$, $p=.844$ and of Time, $F(1, 160.53)=0.41$, $p=0.390$ were non-significant. There was a significant Group x Time interaction, $F(1,160)=8.18$, $p=.005$. Pairwise comparisons revealed significant reductions in Accuracy in the relaxation group post-intervention ($M=94.80$, 95%CI[93.16,96.16]) relative to pre-intervention ($M=96.43$, 95%CI[94.95,97.91]), $F(1, 158)=6.45$, $p=.012$. There was no significant difference in Accuracy between pre- and post-intervention for the mindfulness group.

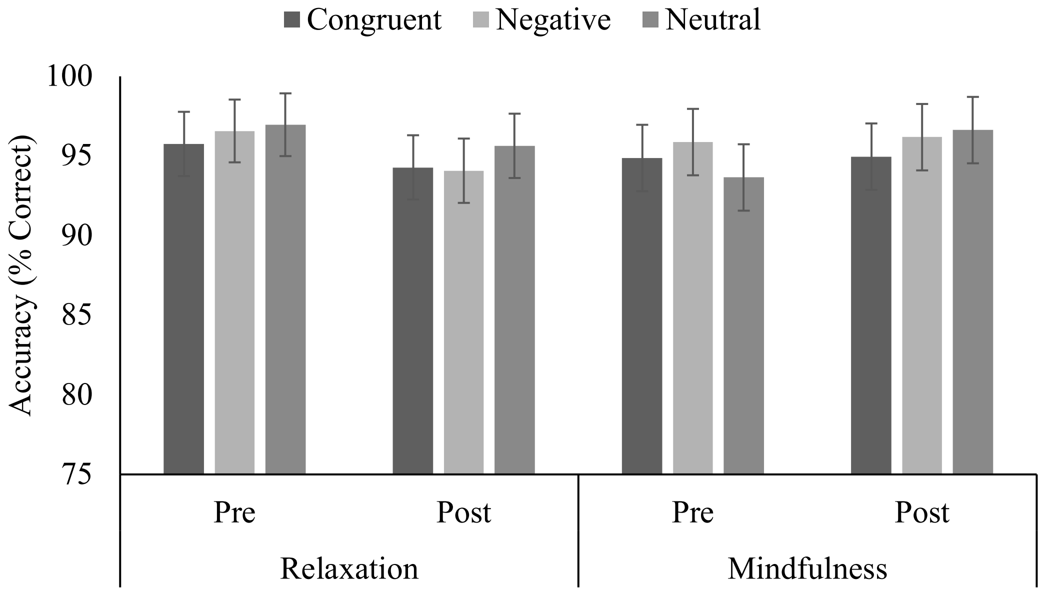

Figure 4. Accuracy (% correct) for congruent, negative, and neutral words at pre- and post-intervention for each condition. Error bars denote 95% confidence intervals.

Table 4

Cell Means (SD) for accuracy (%) for all Condition, Group, and Time conditions

		Group			
		Mindfulness		Relaxation	
Time	Condition	*M (SD)*	95% CI *[LL, UL]*	*M (SD)*	95% CI *[LL, UL]*
Pre	Congruent	94.8(5.2)	[92.6,96.9]	95.8(3.4)	[93.7,97.9]
	Neutral	93.6(4.8)	[91.4,95.7]	97.0(3.2)	[94.9,99.0]
	Negative	95.8(4.1)	[93.6,97.9]	96.6(2.0)	[94.5,98.6]
Post	Congruent	94.8(3.9)	[92.6,96.9]	94.3(5.1)	[92.2,96.4]
	Neutral	96.4(3.9)	[94.3,98.6]	95.6(4.5)	[93.5,97.7]
	Negative	96.0(5.1)	[93.8,98.2]	94.1(4.8)	[92.0,96.2]

Note. CI = confidence interval; *LL* = lower limit; *UL* = upper limit

Discussion

The current study aimed to examine the effect of one-week (20-minutes per day) of neurofeedback-based mindfulness training on executive attention relating to emotional processing and emotion regulation, relative to a neurofeedback-based relaxation control condition. Between two experimental sessions, conditions were compared on reaction time, accuracy, and emotion regulation in response to an emotional Stroop task and the S-DERS, respectively. For the emotional Stroop task, there was an overall main effect of Condition, such that RT was reduced for congruent words relative to neutral and negative words, which indicated the presence of task conflict when responding to non-colour words relative to colour-congruent words. In contrary to predictions, there was no significant difference between neutral and negative word conditions, indicating the absence of an emotional Stroop effect.

The hypotheses that participants in the mindfulness group would show reductions in task conflict and emotional interference post-intervention relative to pre-intervention were not supported as evidenced by a non-significant Group by Time by Condition interaction. However, the main effect of Time was significant, indicating that participants in both groups showed overall improvements in RT following the intervention. Nonetheless, only participants in the relaxation group showed significant reductions in accuracy post-intervention, whereas there was no change in the mindfulness group. This may suggest that the decreased RT post-intervention for participants in the relaxation group can be partially explained by a reduction in accuracy (i.e. a speed accuracy trade-off).

There were no significant differences between groups on any of the control questionnaire measures at baseline, indicating equivalence of groups. For the S-DERS, the main effects of Time and Group and the hypothesised Group by Time interaction were not significant. Also contrary to predictions, there were no Group by Time interactions for any other outcome measures, indicating that mindfulness and relaxation had minimal influence on self-reported mood, state anxiety, and state mindfulness. In summary, this pattern of findings indicates that mindfulness training improved ES task processing overall, but did not show improvements in executive functions that are involved in emotion regulation and in subjective measures of mindfulness and wellbeing. These findings are both in accordance and in conflict with previous literature examining the effects of mindfulness.

Stroop and Emotional Stroop Interference

According to Buddhist tradition, the human condition is characterised as being bound by habitual emotional reactions, in that we react to our thoughts and emotions as if they are true representations of reality, rather than subjective and transient events (Hölzel et al., 2011). Reacting in such a way can result in elaborative processing of the stimuli, thereby reducing one's attentional capacity to process information in the present moment (Posner, 1978). However, Buddhist tradition has prescribed mindfulness meditation as a metacognitive practice that can help overcome maladaptive fixation with one's internal states through cultivation of attentional control, cognitive flexibility, and emotion regulation (Bhayee et al., 2016; Bishop et al., 2004). As such, the emotional Stroop task was used to assess the effects of a mindfulness intervention on one's ability to inhibit elaborative processing of emotionally valanced stimuli.

Contrary to predictions, results revealed that the mindfulness intervention did not reduce emotional interference. This is in line with both Allen et al. (2012) and Lee and Orsillo (2014) who did not find an emotional interference effect in healthy participants. However, Allen et al. (2012) did find that mindfulness training adherence was a strong predictor of brain regions that are involved in processing negative stimuli. In contrast, Ortner et al. (2007) found that meditators showed less emotional interference than a relaxation and waitlist control condition following 7 weeks of training. However, each of these studies used different measures of emotional interference. For example, Allen et al. (2012) measured interference using a number-counting Stroop with emotionally valanced images, whereas Lee and Orsillo (2014) used a word-card version of the emotional Stroop task, and Ortner et al. (2007) had participants judge the pitch of a tone while being presented with emotional pictures. These differences in task methodology makes comparison of studies challenging.

Emotion Regulation

Mindfulness meditation involves a metacognitive awareness of one's thoughts and feelings and an attempt to disengage from them, which is suggested to facilitate emotion regulation abilities (Coffey et al., 2010). Indeed, Coffey et al.'s (2010) path analysis demonstrated that emotion regulation and mindfulness possess overlapping constructs (Coffey et al., 2010). Previous research has also identified improvements in emotion regulation abilities following brief mindfulness interventions (Broderick & Metz, 2009) and correlations between these constructs at the neurological level (Goldin & Gross, 2010; Modinos et al., 2010). As such, the non-significant Group by Time interaction was surprising in light of this previous research.

One potential explanation for the null results in the current study is that the emotional interference effect may not be evident in healthy participants. While some studies have found emotional interference effects in both healthy and clinical populations (eg. Feng et al., 2018; Ortner et al., 2007), others suggest that the interference effect is limited to individuals with clinical disorders (Malinowski, Moore, Mead, & Gruber, 2017). This is in line with Attentional Control Theory (Eysenck et al., 2007) which suggests that anxiety increases attention to threat-related stimuli which simultaneously decreases attentional control and processing efficiency. In support of this, Thomas, Johnstone, and Gonsalvez (2007) did not find emotional interference effects at the reaction time level, although they did find increased P3 amplitude in response to threatening words in a sample of healthy participants. They explained that this increased amplitude may be due to the enhanced salience of the threatening stimuli. They concluded that event-related potentials (ERPs) allow a finer examination of attention-related mental processing than reaction time. As such, while the current study involving healthy participants did not identify an emotional interference effect at the reaction time level, measuring interference using ERPs may have provided a more direct measure of attentional processing of emotional stimuli following the mindfulness intervention.

Another potential explanation for the null findings in the current study is that the brevity of the intervention may not have been robust enough to influence levels of mindfulness, executive functioning, or emotion regulation. Considering mindfulness is a cultivated skill that requires repeated practice, especially for it to become automatic (Gratz & Roemer), changes in executive functioning and emotion regulation may be better captured following longer durations (Lykins & Baer, 2009). In line with this, other studies have found mindfulness meditation experience and training adherence to be significantly associated with levels of mindfulness, emotion regulation abilities, and performance on various measures of attention including the Stroop task (Baer et al., 2009; Moore & Malinowski, 2009; Ortner et al., 2007). As such, the length of the intervention in the current study may not have been long enough to produce the hypothesised effects, which may be considered a key limitation.

Design and Methodological Limitations

Factors within the design of this study may explain the null findings. The timing of when participants completed the experimental sessions may have limited the ability to detect changes in the outcome measures. It is possible that participants felt less anxious and more mindful initially following the training, but these salutary effects may have dissipated in the time between testing. Indeed, other brief interventions that have found improvements on these variables have tested their participants immediately following the mindfulness exercise (Ortner, Kilner, & Zelazo, 2007).

While there is considerable research outlining the overlap between mindfulness and emotion regulation (Baer et al., 2006), other studies have suggested that the aims of these practices are conceptually distinct (Finkelstein-Fox, Park, & Riley, 2018), which presents an issue of internal validity in the current study. While both focus on acknowledging and accepting one's thoughts and feelings, they differ in that the goal of emotion regulation is to adaptively alter one's emotion experience, whereas the aim of mindfulness is to non-judgementally accept one's emotional state (Finkelstein-Fox, Park, & Riley, 2018). As such, the cultivation of any mindfulness qualities such as decentration and a non-judgemental awareness and acceptance of one's thoughts and emotions may not be captured with the S-DERS. Nonetheless, there were no changes in state mindfulness following the intervention, and therefore the extent to which these inferences can be drawn is limited.

State mindfulness did not increase in the mindfulness condition, which may suggest that the mindfulness manipulation was unsuccessful, or did not sufficiently differ from the relaxation manipulation. For example, the relaxation intervention required participants to relax by focusing their attention on a visual scene and receive neurofeedback based on their galvanic skin response (GSR). GSR is a measure of sweat gland activity, which serves as an index of physiological activity (autonomic activation) related to emotional states and emotional processing (Critchley, 2002). There were no clear instructions provided regarding the exact method by which participants relaxed. As such, it is possible that they relaxed by regulating their emotions or disengaging from their thoughts based on the neurofeedback they received. Additionally, the intervention required participants to focus on the visual stimulus which may have enhanced their attentional control. Evidently, this intervention may not have differed considerably from the mindfulness intervention, whereby participants were instructed to disengage from their thoughts by focusing their attention on the breath. Indeed, Wenk-Sormaz (2005) suggests that mindfulness meditation is similar to other self-regulating practices such as progressive relaxation and neurofeedback, in that they all involve an attempt to control attention. As such, it is possible that the mindfulness intervention did not sufficiently differ from the relaxation intervention.

The current study was slightly underpowered, which may have reduced the likelihood of detecting a significant effect. The power calculation indicated 40 participants to be sufficient to detect a moderate effect, although the final sample comprised only 33. The small sample size also limited the opportunity to examine effects of covariates such as training adherence or trait mindfulness or anxiety on the relationship between mindfulness training and ES task performance, emotion regulation, and the outcome measures. This would have been insightful given previous research on the association between these variables. For example, the associations between training adherence and levels of mindfulness, emotion regulation, and attentional performance, and activation of brain regions when processing negative stimuli (Allen et al., 2012; Baer et al., 2009; Moore & Malinowski, 2009; Ortner et al., 2007), between trait mindfulness and reduced emotional suppression and acceptance of negative stimuli (Schutze, Rees, Preece, & Schutze, 2010) and between anxiety and attentional bias towards threatening stimuli (Lee & Orsillo, 2014). Nonetheless, the longitudinal design and use of mixed models improved the power of the ES task analyses (Zeller, Yuval, Nitzan-Assayag, & Bernstein, 2015). However, the longitudinal nature of the study may have biased the results due to practice effects as a result of repeated assessments (Anstey & Hofer, 2004).

Despite these shortcomings, the current study had several strengths. Firstly, implementing the mindfulness and relaxation interventions with an external device allowed us to obtain objective measures of training adherence via the in-app data that is provided. The use of an external device also allowed us to overcome issues of accessibility due to variation in participant’s university and work schedules. Another strength was the employment of an active relaxation control condition so that the effects of mindfulness practice could be distinguished from the effects of relaxation alone. Despite prevailing evidence that mindfulness involves a relaxation response that may partially explain its salutary effects, previous research does not always account for this. Moreover, assessing equivalence of groups on various control measures ensured that the results were not due to confounding variables. Additionally, the emotional Stroop task used in the current study was methodologically rigorous as it was created in line with recommendations from the most recent literature. For example, emotional interference was calculated using response latencies which has higher test-retest reliability than calculating interference with difference scores (Strauss et al).

Implications and Future Research

The current study did not find improvements in attentional control at the reaction time level, although there may have been underlying changes in neural activity. As such, future research should aim to replicate this study using ERPs or neuroimaging to examine the neural processes associated with attentional processing of threatening stimuli in participants practicing mindfulness. Additionally, replicating this study over a longer duration may increase the likelihood of identifying improvements in wellbeing and attentional control. Furthermore, a larger sample size would provide more power which may further increase this likelihood, and allow more flexibility in the analyses that can be conducted. Additionally, the inclusion of an active control condition without neurofeedback would allow delineation of the effects of neurofeedback from the mindfulness practice itself. A waitlist control condition would also help control for these effects, as well as effects due to motivation (Jensen et al., 2012). Moreover, given the enhanced emotional Stroop effect in clinical populations, future research should replicate this study with individuals with psychopathologies that relate to the words used, for example, the word 'calories' with individuals with Anorexia Nervosa, which may have clinical implications.

To the best of our knowledge, this is the first experiment to investigate the effects of a neurofeedback-based mindfulness intervention on emotional interference and emotion regulation. While the availability of mindfulness-based mobile applications is extensive, research supporting their effectiveness is limited. As such, the current study adds to this scarce literature, with the addition of neurofeedback.

Considering mindfulness is characterised by an awareness and acceptance of one's thoughts and emotions, and inhibition of elaborate processing of stimuli, the current study expected to find improvements in emotional interference and emotion regulation. However, the results revealed that one week of mindfulness training did not influence these domains, which is both in accordance and conflict with previous research. While the current findings provide limited evidence for improvements in attention and emotion regulation following a mindfulness intervention, it provides a useful examination of the current literature and recommendations for future research. Given the salutary effects that mindfulness may have on wellbeing and attention, future research addressing the limitations of the current study is encouraged.

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Appendix A

Online Screening Questionnaire

[Note: Information Sheet was inserted at beginning of Screening Survey]
By clicking next, you are signalling your consent to complete the screening survey, and if contacted, you will be free to decide whether you would like to participate in the study. You are also free to decline to answer any questions. However, researchers may call or email to clarify any missing answers prior to confirming eligibility.

Demographics
Please enter your first name ________________.
Please enter your email address ________________.
Please enter your phone number ________________.
How old are you? ________________.
What is your biological sex? Male: ☐ Female: ☐ No answer: ☐
Are you right or left handed? Right: ☐ Left: ☐ No answer: ☐
Is English your first language? Y: ☐ N: ☐ No answer: ☐
Are you currently pregnant or trying to become pregnant? Y: ☐ N: ☐ No answer: ☐
Health
Do you have sensitive skin? Y: ☐ N: ☐ No answer: ☐
Have you ever experienced (or been diagnosed with) any of the following: Epilepsy Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐ Fits / seizures Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐ Regular giddiness/fainting Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐ Severe / multiple concussions Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐ Severe head injury Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐ Brain surgery Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐ Loss of consciousness (more than 2 minutes) Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐

Diabetes Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Heart Condition Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Sleep disorder (or any major sleeping difficulties) Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Visual problems (not corrected by glasses/lenses) Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Auditory problems Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Any other serious physical condition Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Any other neurological condition Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
ADHD/ADD Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Dyslexia Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Learning difficulties Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Current depression / anxiety Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Past depression / anxiety Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
Other mental health conditions (e.g., mania, psychosis, schizophrenia, PTSD, OCD, substance dependence etc) Y: ☐ N: ☐ Uncertain: ☐ No answer: ☐
If you answered yes or uncertain to any of the above, please provide some brief details (or the researchers can ask by phone if you prefer): ________________________________
Are you currently taking any prescribed medications? Y: ☐ N: ☐ No answer: ☐ If yes, please list the name of the medications: _____________________________________ ____ .

<u>Substance use</u>

The following questions are about your use of tobacco and alcohol

In the last 6 months, how often have you used tobacco/nicotine?

Never 0
Less than monthly 1
Monthly 2
Weekly 3
Daily or almost daily 4

State Trait Anxiety Inventory (STAI)

SELF-EVALUATION QUESTIONNAIRE

STAI Form Y-2

Name____ Date__________

DIRECTIONS

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate value to the right of the statement to indicate how you *generally feel.* There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe how you generally feel.

	ALMOST NEVER	SOMETIMES	OFTEN	ALMOST ALWAYS
21. I feel pleasant	1	2	3	4
22. I feel nervous and restless	1	2	3	4
23. I feel satisfied with myself	1	2	3	4
24. I wish I could be as happy as others seem to be	1	2	3	4
25. I feel like a failure	1	2	3	4
26. I feel rested	1	2	3	4
27. I am "calm, cool, and collected"	1	2	3	4
28. I feel that difficulties are piling up so that I cannot overcome them	1	2	3	4
29. I worry too much over something that really doesn't matter	1	2	3	4
30. I am happy	1	2	3	4
31. I have disturbing thoughts	1	2	3	4
32. I lack self-confidence	1	2	3	4
33. I feel secure	1	2	3	4
34. I make decisions easily	1	2	3	4
35. I feel inadequate	1	2	3	4
36. I am content	1	2	3	4
37. Some unimportant thought runs through my mind and bothers me	1	2	3	4
38. I take disappointments so keenly that I can't put them out of my mind	1	2	3	4
39. I am a steady person	1	2	3	4
40. I get in a state of tension or turmoil as I think over my recent concerns and interests	1	2	3	4

Meditation / Relaxation Experience Questionnaire

Have you had any experience with the following forms of meditation/relaxation?

	Yes	No
Mindfulness training (including MBSR MBCBT, IBMT, MiCT, ACT, etc)		
Zen		
Vipassana		
Shamatha		
Vipashyana		
Shavasana		
Meditative contemplation		
Sadhana		
Mahamudra		
Breathing meditation		
Walking meditation		
Compassion meditation (tonglen, metta, loving, kindness, etc.)		
Ngondro		
TM		
Tai Chi		
Yoga		
Qigong		
Relaxation exercises (e.g., progressive muscle relaxation)		
Other.............. (please specify)		

In the past year, how much time have you spent practicing any form of meditation / relaxation per week?

None
Less than 15 mins
15-30 mins
30-60 mins
1-2 hours
2-5 hours
More than 5 hours

Which forms of meditation / relaxation have you practiced in the past year?

____

In your lifetime, how many hours have you spent practicing meditation / relaxation?

None
Less than 1 hours
1-5 hours
5-10 hours
10-20 hours
More than 20 Hours

Which forms of meditation / relaxation have you practiced for more than 5 hours in your lifetime?

____

15-item Five-Facet Mindfulness Questionnaire (FFMQ-15)

FFMQ-15: 15-item Five-Facet Mindfulness Questionnaire

Instructions

Please use the 1 (never or very rarely true) to 5 (very often or always true) scale provided to indicate how true the below statements are of you. Circle the number in the box to the right of each statement which represents your own opinion of what is generally true for you. For example, if you think that a statement is often true of you, circle '4' and if you think a statement is sometimes true of you, circle '3'.

	Never or very rarely true	Rarely true	Sometimes true	Often true	Very often or always true
1. When I take a shower or a bath, I stay alert to the sensations of water on my body.	1	2	3	4	5
2. I'm good at finding words to describe my feelings.	1	2	3	4	5
3. I don't pay attention to what I'm doing because I'm daydreaming, worrying, or otherwise distracted.	1	2	3	4	5
4. I believe some of my thoughts are abnormal or bad and I shouldn't think that way.	1	2	3	4	5
5. When I have distressing thoughts or images, I "step back" and am aware of the thought or image without getting taken over by it.	1	2	3	4	5
6. I notice how foods and drinks affect my thoughts, bodily sensations, and emotions.	1	2	3	4	5
7. I have trouble thinking of the right words to express how I feel about things.	1	2	3	4	5
8. I do jobs or tasks automatically without being aware of what I'm doing.	1	2	3	4	5
9. I think some of my emotions are bad or inappropriate and I shouldn't feel them.	1	2	3	4	5
10. When I have distressing thoughts or images I am able just to notice them without reacting.	1	2	3	4	5
11. I pay attention to sensations, such as the wind in my hair or sun on my face.	1	2	3	4	5
12. Even when I'm feeling terribly upset I can find a way to put it into words.	1	2	3	4	5
13. I find myself doing things without paying attention.	1	2	3	4	5
14. I tell myself I shouldn't be feeling the way I'm feeling.	1	2	3	4	5
15. When I have distressing thoughts or images I just notice them and let them go.	1	2	3	4	5

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The mini International Personality Item Pool (IPIP) scale

Instructions: On the following pages, there are phrases describing people's behaviors. Please use the rating scale below to describe how accurately each statement describes you. Describe yourself as you generally are now, not as you wish to be in the future. Describe yourself as you honestly see yourself, in relation to other people you know of the same sex as you are, and roughly your same age. So that you can describe yourself in an honest manner, your responses will be kept in absolute confidence. Please read each statement carefully, and then fill in the bubble that corresponds to the number on the scale.

1=Very Inaccurate
2=Moderately Inaccurate
3=Neither Inaccurate nor Accurate
4=Moderately Accurate
5=Very Accurate

1. Am the life of the party (E)
2. Sympathize with others' feelings (A)
3. Get chores done right away (C)
4. Have frequent mood swings (N)
5. Have a vivid imagination (I)
6. Don't talk a lot (E)
7. Am not interested in other people's problems (A)
8. Often forget to put things back in their proper place (C)
9. Am relaxed most of the time (N)
10. Am not interested in abstract ideas (I)
11. Talk to a lot of different people at parties (E)
12. Feel others' emotions (A)
13. Like order (C)
14. Get upset easily (N)
15. Have difficulty understanding abstract ideas (I)
16. Keep in the background (E)
17. Am not really interested in others (A)
18. Make a mess of things (C)
19. Seldom feel blue (N)
20. Do not have a good imagination (I)

Note: Items 6, 7, 8, 9, 10, 15, 16, 17, 18, 19, and 20 are reverse scored.

Video G aming Experience

Video Game Questionnaire – version March 2018

Video Game Playing Questionnaire – *DURING* THE PAST YEAR

Ss ID: ______________________________ Date: ______________

For each category of games, please rate:

1. Your estimated EXPERTISE in that category (1 = lowest, 7 = highest) – even if no experience, how do you think you would perform, compared to the general public?
2. Your average HOURS PER WEEK in that category for the past 12 months.
   Ex: If you play 1.5 hrs/week, mark "1+ to 3"
3. The games you played and how old you were when you played them most

ACTION_FIRST/THIRD PERSON SHOOTERS (Call Of Duty, Halo, Battlefield, Half-Life, Overwatch, Counterstrike ...)
Expertise: **1 2 3 4 5 6 7** Hours per week: **Never 0+ to 1 1+ to 3 3+ to 5 5+ to 10 10+**
Games played most over the past year:
____

ACTION_RPG/ADVENTURE (The Witcher, Mass Effect, Fallout 4, Skyrim, GTA, Assassin's Creed, Tomb Raider, The Last of Us, ...)
Expertise: **1 2 3 4 5 6 7** Hours per week: **Never 0+ to 1 1+ to 3 3+ to 5 5+ to 10 10+**
Games played most over the past year:
____

SPORTS/DRIVING (Fifa, NHL, Mario Kart, Need for Speed, Forza, ...)
Expertise: **1 2 3 4 5 6 7** Hours per week: **Never 0+ to 1 1+ to 3 3+ to 5 5+ to 10 10+**
Games played most over the past year:
____

REAL-TIME STRATEGY/MOBA (Starcraft, Warcraft (old ones:I, II & III), DotA, Command & Conquer, League of Legends, Age of Empires, ...)
Expertise: **1 2 3 4 5 6 7** Hours per week: **Never 0+ to 1 1+ to 3 3+ to 5 5+ to 10 10+**
Games played most over the past year:
____

NON-ACTION TURN-BASED ROLE-PLAYING/FANTASY (Final Fantasy, Fable, Pokemon, Dragon Age, ...)
Expertise: **1 2 3 4 5 6 7** Hours per week: **Never 0+ to 1 1+ to 3 3+ to 5 5+ to 10 10+**
Games played most over the past year:
____

TURN-BASED STRATEGY/LIFE SIMULATION/PUZZLE (Civilization, Hearthstone, The Sims, Restaurant Empire, Puzzle Quest, Bejeweled, Solitaire, Candy Crush, ...)
Expertise: **1 2 3 4 5 6 7** Hours per week: **Never 0+ to 1 1+ to 3 3+ to 5 5+ to 10 10+**
Games played most over the past year:
____

MUSIC GAMES (Guitar Hero, Dance Dance Revolution, Rock Band, ...)
Expertise: **1 2 3 4 5 6 7** Hours per week: **Never 0+ to 1 1+ to 3 3+ to 5 5+ to 10 10+**
Games played most over the past year:
____

OTHER (Games that don't fit into any other category, Phone games, Browser games, Fighting games, etc.)
Expertise: **1 2 3 4 5 6 7** Hours per week: **Never 0+ to 1 1+ to 3 3+ to 5 5+ to 10 10+**
Games played most over the past year:
____

Thank you for completing the screening survey. If you are eligible to participate, the researchers will contact you, and you will be free to choose whether to participate in the experiment.

Please note: If you are feeling distressed, there are list of free counselling services below that you can access free of charge.

Beyond Blue	Lifeline Australia	Mental Health Helpline (TAS)
1300 224 636	13 11 14	1800 332 388
www.beyondblue.org.au	www.lifeline.org.au	www.dhhs.tas.gov.au/mentalhealth

Appendix B

Experimental Session Questionnaire

Experimental Session Screening Questionnaire
Have you abstained from illicit drugs since first contact from the experimenter? Yes: ☐
Have you consumed alcohol within the last 24 hours? Yes: ☐ No: ☐
How many cups of coffee (or other caffeinated products) have you consumed today? ________________. If yes: many hours has it been since your last? ________________.
Have you had any tobacco or nicotine products today? Yes: ☐ No: ☐ *If yes:* how many cigarettes / nicotine products have you had today? ________________. *If yes:* how many hours since your last cigarette or nicotine product? ________________.
Have you consumed any medications in the past week) Yes: ☐ No: ☐ *If yes,* please detail: Medication Estimated dose Number of occasions taken Time since last taken 1. ____________ 2. ____________ 3. ____________ 4. ____________ 5. ____________
Are you an undergraduate psychology student completing this study for course credit? Yes: ☐ No: ☐
Karolinska Sleepiness Scale Please circle on the following scale of 1 to 9 how you feel AT THE PRESENT MOMENT: 1. Extremely alert 2. Very alert 3. Alert 4. Rather alert

5. Neither alert nor sleepy
6. Some signs of sleepiness
7. Sleepy, but no effort to keep awake
8. Sleepy, some effort to keep awake
9. Very sleepy, great effort to keep awake, fighting sleep

Profile of Mood States-Short Form

Below is a list of words that describe feelings people have. Please read each one carefully. Then circle ONE answer to the right, which best describes how you are feeling AT THE MOMENT.

The numbers refer to these phrases:
0=not at all
1=a little
2=moderately
3=quite a bit
4= extremely

1. **Tense................0 1 2 3 4**
2. **Angry................0 1 2 3 4**
3. **Worn out..........0 1 2 3 4**
4. **Unhappy...........0 1 2 3 4**
5. **Lively................0 1 2 3 4**
6. **Confused..........0 1 2 3 4**
7. **Peeved..............0 1 2 3 4**
8. **Sad....................0 1 2 3 4**
9. **Active................0 1 2 3 4**
10. **On Edge...........0 1 2 3 4**
11. **Grouchy............0 1 2 3 4**
12. **Blue..................0 1 2 3 4**
13. **Energetic........ 0 1 2 3 4**
14. **Hopeless..........0 1 2 3 4**
15. **Uneasy.............0 1 2 3 4**
16. **Restless............0 1 2 3 4**
17. **Unable to Concentrate.....0 1 2 3 4**
18. **Fatigued...........0 1 2 3 4**
19. **Annoyed..........0 1 2 3 4**
20. **Discouraged.............0 1 2 3 4**
21. **Resentful.................0 1 2 3 4**
22. **Nervous....................0 1 2 3 4**
23. **Miserable..................0 1 2 3 4**
24. **Cheerful...................0 1 2 3 4**
25. **Bitter.........................0 1 2 3 4**
26. **Exhausted.................0 1 2 3 4**
27. **Anxious.....................0 1 2 3 4**
28. **Helpless....................0 1 2 3 4**
29. **Weary........................0 1 2 3 4**
30. **Bewildered...............0 1 2 3 4**
31. **Furious......................0 1 2 3 4**
32. **Full of pep.................0 1 2 3 4**
33. **Worthless.................0 1 2 3 4**
34. **Forgetful...................0 1 2 3 4**
35. **Vigorous....................0 1 2 3 4**
36. **Uncertain about things......................0 1 2 3 4**
37. **Bushed.......................0 1 2 3 4**

Cognitive and Affective Mindfulness Scale (CAMS-R)

The Cognitive and Affective Mindfulness Scale – Revised (CAMS-R)

The CAMS-R is a 12-item measure designed to capture a broad conceptualization of mindfulness with language that is not specific to any particular type of meditation training.

Feldman, G., Hayes, A., Kumar, S. et al. J Psychopathol Behav Assess (2007) 29: 177. doi:10.1007/s10862-006-9035-8

Instructions: People have a variety of ways of relating to their thoughts and feelings. For each of the items below, rate how much each of these ways applies to *you*.

_______ 1. It is easy for me to concentrate on what I am doing.
_______ 2. I am preoccupied by the future.
_______ 3. I can tolerate emotional pain.
_______ 4. I can accept things I cannot change.
_______ 5. I can usually describe how I feel at the moment in considerable detail.
_______ 6. I am easily distracted.
_______ 7. I am preoccupied by the past.
_______ 8. It's easy for me to keep track of my thoughts and feelings.
_______ 9. I try to notice my thoughts without judging them.
_______ 10. I am able to accept the thoughts and feelings I have.
_______ 11. I am able to focus on the present moment.
_______ 12. I am able to pay close attention to one thing for a long period of time.

Scoring: Items 2, 6, and 7 are reverse-scored. After appropriate reversals, sum values for items 1 - 12. Higher values reflect greater mindful qualities.

Mindfulness Attention Awareness Scale (MAAS)

The Mindful Attention Awareness Scale (MAAS)

The trait MAAS is a 15-item scale designed to assess a core characteristic of mindfulness, namely, a receptive state of mind in which attention, informed by a sensitive awareness of what is occurring in the present, simply observes what is taking place.

Brown, K.W. & Ryan, R.M. (2003). The benefits of being present: Mindfulness and its role in psychological well-being. *Journal of Personality and Social Psychology, 84,* 822-848.

Carlson, L.E. & Brown, K.W. (2005). Validation of the Mindful Attention Awareness Scale in a cancer population. *Journal of Psychosomatic Research, 58,* 29-33.

Instructions: Below is a collection of statements about your everyday experience. Using the 1-6 scale below, please indicate how frequently or infrequently you currently have each experience. Please answer according to what really reflects your experience rather than what you think your experience should be. Please treat each item separately from every other item.

1	2	3	4	5	6
almost always	very frequently	somewhat frequently	somewhat infrequently	very infrequently	almost never

_____ 1. I could be experiencing some emotion and not be conscious of it until some time later.
_____ 2. I break or spill things because of carelessness, not paying attention, or thinking of something else.
_____ 3. I find it difficult to stay focused on what's happening in the present.
_____ 4. I tend to walk quickly to get where I'm going without paying attention to what I experience along the way.
_____ 5. I tend not to notice feelings of physical tension or discomfort until they really grab my attention.
_____ 6. I forget a person's name almost as soon as I've been told it for the first time.
_____ 7. It seems I am "running on automatic," without much awareness of what I'm doing.
_____ 8. I rush through activities without being really attentive to them.
_____ 9. I get so focused on the goal I want to achieve that I lose touch with what I'm doing right now to get there.
_____ 10. I do jobs or tasks automatically, without being aware of what I'm doing.
_____ 11. I find myself listening to someone with one ear, doing something else at the same time.
_____ 12. I drive places on 'automatic pilot' and then wonder why I went there.
_____ 13. I find myself preoccupied with the future or the past.
_____ 14. I find myself doing things without paying attention.
_____ 15. I snack without being aware that I'm eating.

Scoring: To score the scale, simply compute a mean (average) of the 15 items.

State Difficulties with Emotion Regulation Scale (S-DERS)

1------------------------2------------------------3------------------------4-------------------------5
Not at all Somewhat Moderately Very much Completely

Instructions: Please read each statement and indicate how much it applies to **YOUR EMOTIONS RIGHT NOW.**

____ 1) I feel guilty for feeling this way. (1)

____ 2) I am paying attention to how I feel (r) (3)

____ 3) I feel out of control (4)

____ 4) I am embarrassed for feeling this way. (7)

____ 5) I am feeling very bad about myself. (8)

____ 6) I am acknowledging my emotions. (r) (10)

____ 7) I have no idea how I am feeling. (11)

____ 8) I feel ashamed with myself for feeling this way. (12)

____ 9) I am having difficulty doing the things I need to do right now. (14)

____ 10) I believe that I will continue feeling this way for a long time. (15)

____ 11) I care about what I am feeling. (r) (16)

____ 12) I am angry with myself for feeling this way. (17)

____ 13) I am having difficulty controlling my behaviors. (18)

____ 14) I am confused about how I feel. (19)

____ 15) I believe that I am going to end up feeling very depressed. (21)

____ 16) I am taking time to figure out what I am really feeling. (r) (22)

____ 17) My emotions feel out of control. (23)

____ 18) I am irritated with myself for feeling this way. (24)

____ 19) I believe that my feelings are valid and important. (r) (26)

____ 20) I feel like I'm a weak person for feeling this way. (27)

____ 21) My emotions feel overwhelming. (28)

Training Outcome Questionnaire

Now that you have received instructions on your training task over the next week, please answer the following questions:

	1 Not at all	2	3	4	5 Some what	6	7	8	9 Very much
Do you think this training is likely to improve your attention?									
Do you think this training is likely to improve your ability to complete the computer tasks?									
Do you think this training is likely to improve your emotional wellbeing?									

Appendix C

Emotional and Neutral Words Used in the Emotional Stroop Task

Neutral Words	**Negative Words**
LINK	RAGE
WIRE	FAIL
FOOT	EVIL
PARK	PAIN
SEND	HATE
NAVEL	GLOOM
THUMB	GRIEF
BREAD	CRASH
WAGON	PANIC
CLOCK	ANGRY
WILLOW	SORROW
BRANCH	MISERY
POTATO	TRAGIC
SENIOR	SCREAM
LEAGUE	CRISIS

Appendix D

Task Instructions

Instructions – Mindfulness/Muse

1. Locate yourself in a quiet room where you won't be distracted.
2. Sit down on a comfortable chair or cushion with your back straight. You can sit with your legs crossed or out in front of you, and you can wrap a blanket around you for warmth and comfort if you wish.
3. Ensure the Muse headband is **fully charged** by tapping the power button to display power level [look for 5 lights].
4. Open the **Muse app** on your phone
5. Login with your account.
6. Place the Muse headband over your ears and forehead.
7. On the 'Meditate' screen, ensure the following options are selected:
    a. **Length:** 10 or 20 minutes (depending on the day)
    b. **Soundscape:** Rainforest
    c. **Exercise:** Intro to Muse.
        i. **Note:** You can find 'Intro to Muse' within the **Muse Essentials** option. This study will progress through the **10** Muse Essentials courses.
        ii. See the **'Daily Task Schedule'** below for details on which course you should choose on which day and the duration.
8. **Calibration** will then begin. Listen to the instructions and adjust the headband as necessary.
9. Listen to the audio instructions. It is important that you listen to the entire instructions (although you don't need to listen to the instructions for every new session).
10. Click "Skip to results"
11. Click "Save".

Each day for 7 days, complete **the following sessions.**

<u>Daily Task Schedule:</u>

Day 1:
Intro to Muse (10 minutes)
Training a Puppy (10 minutes)

Day 2:
Sensation of Breath (10 minutes)
Counting Breaths (10 minutes)

Day 3:
Sitting Comfortably (10 minutes)
Finding your Soundscape (10 minutes)

Day 4:
Dealing with Distraction (20 minutes)

Day 5:
Working with Discomfort (20 minutes)

Day 6:
Lowering the Bar (20 minutes)

Day 7:
Bridging to Daily Life (20 minutes)

Trouble shooting

If you are having **issues connecting** your phone with the Muse headband:

- Make sure location is enabled on the phone or tablet
- If you are using/intend to use Apple AirPods, make sure those are connected before connecting the headband
- If 'Problems Connecting' appears, tap on the prompt and select the corresponding headband device.
- User guide for further troubleshooting is available at https://tinyurl.com/MuserGuide

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If anything goes wrong (e.g. the app or device won't work, calibration won't work, etc.) or if you have any questions at all, please contact any of the following researchers

James Brady
Ph: 04.........
Email: james.brady@utas.edu.au

Bronte Matthews
Ph: 04.........
Email: brontem2@utas.edu.au

Safety Information

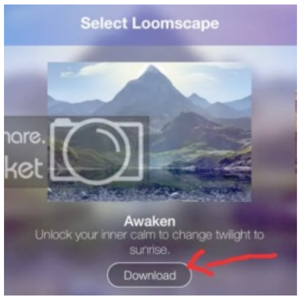
- In rare cases, people experience seizures or blackouts due to exposure to flashing lights and patterns created by the display of certain applications on mobile or other such similar devices.
- If you have done so, or have experienced any nausea, involuntary movements, tingling, numbness, or vision issues while using such devices in the past, you should consult with your doctor before using similar applications and should immediately cease all such use of such applications should the symptoms re-occur.
- In any event you should avoid prolonged use of such applications to minimize any possible discomfort or fatigue, including any muscle, joint or eye strain and should closely monitor your children's use of technology to avoid possible problems.

Hardware Safety

- Do not dispose of MUSE into fire or hot oven, or mechanically crush or cut the MUSE or the battery contained within, as this may result in an explosion.
- Do not expose the MUSE to an extremely high temperature environment, as this may result in an explosion or the leaking of flammable liquid or gas.
- Do not expose the MUSE to extremely low air pressure, as that may result in an explosion or the leakage of flammable liquid or gas.

Instructions – PIP device

1. Locate yourself in a quiet room where you won't be distracted.
2. Sit down on a comfortable chair or cushion with your back straight. You can sit with your legs crossed or out in front of you, and you can wrap a blanket around you for warmth and comfort if you wish.
3. Ensure your mobile phone's **Bluetooth connectivity** option is enabled and the **audio is on.**
4. Ensure the Pip device is **fully charged.** Plug Pip into a USB outlet and ensure the red light is no longer on [fully charged]
5. Open the '**Loom'** app on your mobile phone
6. The first time you open the app, <u>read the instructions</u> by swiping left, then press continue in the top right of the screen.
7. Login to the loom app (if you are not already)
8. Click 'settings' in the top right-hand corner of the home screen (cog symbol) and change **session length** to '**Long'** and ensure **Music** is **'On'**, and then press **'back'**
9. Ensure the pip device is on (hold sensors with thumb and forefinger until the light comes on).



10. Select '**New session'** in the Loom menu
11. <u>If the pip does not automatically connect</u>, follow the instructions on the screen to pair the pip device. This will include holding and releasing the Pip's sensors between your thumb and forefinger (each for 1 second at a time) until a green light flashes.
12. The first time you use the app, <u>check that all three Loomscapes are downloaded</u>**,** and **Install** the additional pictures **'Awaken'** and **'Enchanted forest'** in the Loomscape menu if needed (this will require WiFi or internet connection).
13. Swipe to **select the Loomscape** according to the schedule below, and then press **'continue'**
14. Begin relaxing! Focus on the landscape and try to keep your mind calm and focussed. As you experience relax events (see below) the scene will begin to change, and the progress bar at the bottom of the screen will change from green to blue.
15. View your results after each session

<u>Daily Task Schedule:</u>

Each day for 7 days, complete **the following sessions.** Your sessions should sum to approximately **20 minutes** per day. If the first session takes longer than 15 minutes, choose another short or medium session to complete so that you complete approximately 20mins. Similarly, if the two sessions take less than 20 minutes, choose another short or medium session to make the time up to approx. 20 minutes.

The Pip determines if your stress levels are increasing or decreasing by detecting changes in your electrodermal activity (EDA). There are three types of events which are shown by the colour of the pip symbol in the bottom left of the screen.
Stress events – indicate a short-term increase in EDA
Relax events – indicate a short-term increase in EDA
Steady events – indicate you are neither stressing or relaxing

Day 1:
New life (long session)
Awaken (long session)

Day 2:
Enchanted forest (long session)
New life (long session)

Trouble shooting

If you start a session, and after a few minutes there is no progress (i.e., no change in the visual scene or the progress bar at the bottom of the screen is not changing from blue to green), you could try stopping and restarting the session, or reconnecting or re-pairing the pip device (see below).

Re-connecting the device

Go to 'Menu', Click 'devices', click 'disconnect'
Then click 'connect'

Re-pairing the device

Go to 'Menu', Click 'devices', click 'delete' and then 'ok'
Click 'new pip', and then 'start
Follow the instructions on the screen to pair the device
Once reconnected, select 'back' and then 'New Session' in the Loom menu.

If anything goes wrong (e.g. the app or device won't work etc.) or if you have any questions at all, please contact any of the following researchers:

James Brady
Ph: 04..........
Email: james.brady@utas.edu.au

Bronte Matthews
Ph: 04..........
Email: brontem2@utas.edu.au

Care for Pip device

Protect pip against scratches by storing it in the pouch provided
Regularly clean the gold-plated sensor discs using the carrying pouch to ensure measurement accuracy
Do not get Pip wet or submerge in water or other liquids
Do not expose Pip to extremely high or low temperatures
Do not open, disassemble or attempt to repair Pip

Safety Information

Battery

Pip contains a lithium-polymer battery.
Charge the battery only with the supplied micro USB charging cable. Do not attempt t remove the battery.
The lithium-polymer battery might present a fire or chemical burn hazard or might expl if mistreated
Do not attempt to disassemble, crush, or puncture the battery.
Do not heat the battery above 60 degrees Celsius.

Caution

This device and its antenna(s) must not be co-located or operating in conjunction with an other antenna or transmitter.

Appendix E

Ethics Approval Letter

Human Research Ethics Committee (Tasmania) Network
Research Ethics and Integrity Unit
Office of Research Services

Private Bag 1
Hobart Tasmania
7001
Australia

T +61 3 6226 6254
E human.ethics@utas.edu.au
ABN 30 764 374 782 /CRICOS 00586B

utas.edu.au

07 June 2019

Dr
Allison
Matthew
s C/-
Psycholo
gy,
UTAS

Sent via email

Dear Dr Matthews

REF NO: H0017994
TITLE: The Effects of Video Games and Mindfulness Meditation on Neural Correlates of Attention

Document	*Version*	*Date*
Human Research Ethics Application	v2	
Study Protocol	v2	13May2019
Participant Information Sheet and Consent Form	v2	15May2019
Muse End User License Agreement Terms of Service		
Pip End User License Agreement Terms of Service		

The Tasmania Health and Medical Human Research Ethics Committee (HREC) considered and approved the above documentation on **21 May 2019** to be conducted at the following site(s):

University of Tasmania

Please ensure that all investigators involved with this project have cited the approved versions of the documents listed within this letter and use only these versions in conducting this research project.

This approval constitutes ethical clearance by the Health and Medical HREC. The decision and authority to commence the associated research may be dependent on factors beyond the remit of the ethics review process. For example, your research may need ethics clearance from other organisations or review by your research governance coordinator or Head of Department. It is your responsibility to find out if the approvals of other bodies or authorities are required. It is recommended that the proposed research should not commence until you have satisfied these requirements.

In accordance with the National Statement on Ethical Conduct in Human Research, it is the responsibility of institutions and researchers to be aware of both general and specific legal requirements, wherever relevant. If researchers are uncertain they should seek legal advice to confirm that their proposed research is in compliant with the relevant laws. University of Tasmania researchers may seek legal advice from Legal Services at the University.

All committees operating under the Human Research Ethics Committee (Tasmania) Network are registered and required to comply with the *National Statement on the Ethical Conduct in Human Research* (NHMRC 2007 updated 2018).

Therefore, the Chief Investigator's responsibility is to ensure that:

(1) All investigators are aware of the terms of approval, and that the research is conducted in compliance with the HREC approved protocol or project description.

(2) Modifications to the protocol do not proceed until **approval** is obtained in writing from the HREC. This includes, but is not limited to, amendments that:

- (i) are proposed or undertaken in order to eliminate immediate risks to participants;
- (ii) may increase the risks to participants;
- (iii) significantly affect the conduct of the research; or
- (iv) involve changes to investigator involvement with the project.

Please note that all requests for changes to approved documents must include a version number and date when submitted for review by the HREC.

(3) Reports are provided to the HREC on the progress of the research and any safety reports or monitoring requirements as indicated in NHMRC guidance.
The appropriate forms for reporting such events in relation to clinical and non-clinical trials and innovations can be located at the website below. All adverse events must be reported regardless of whether or not the event, in your opinion, is a direct effect of the therapeutic goods being tested.
http://www.utas.edu.au/research-admin/research-integrity-and-ethics- unit-rieu/human-ethics/human-research-ethics-review-process/health-and-medical- hrec/managing-your-approved-project

(4) The HREC is informed as soon as possible of any new safety information, from other published or unpublished research, that may have an impact on the continued ethical acceptability of the research or that may indicate the need for modification of the project.

(5) All research participants must be provided with the current Participant Information Sheet and Consent Form, unless otherwise approved by the Committee.

(6) This study has approval for four years contingent upon annual review. A *Progress Report* is to be provided on the anniversary date of your approval. Your first report is due **21 May 2020,** and you will be sent a courtesy reminder closer to this due date. Ethical approval for this project will lapse if a Progress Report is not submitted in the time frame provided

(7) A *Final Report* and a copy of the published material, either in full or abstract, must be provided at the end of the project.

(8) The HREC is advised of any complaints received or ethical issues that arise during the course of the project.

(9) The HREC is advised promptly of the emergence of circumstances where a court, law enforcement agency or regulator seeks to compel the release of findings or results. Researchers must develop a strategy for addressing this and seek advice from the HREC.

Should you have any queries please do not hesitate to contact me on (03) 6226 6254 or via email Human.ethics@utas.edu.au.

Yours sincerely

Appendix F

Participant Information Sheet

Study title: The effects of Meditation and Relaxation on Neural Correlates of Attention: A Pilot Study

*Student Researchers: Bronte Matthews, James Brady, Alice Bosworth**
Chief Investigator: Dr Allison Matthews
**This research is being conducted as part of an Honours degree in the Discipline of Psychology, UTAS.*

Invitation
You are invited to participate in a research project looking at the effect of cognitive training interventions on attention. This study will be conducted in the Cognitive Neuroscience Laboratory at the University of Tasmania (Sandy Bay campus).

What is the purpose of this study?
There is some evidence that practices such as meditation and relaxation can change or improve certain aspects of attention. In this study, we are particularly interested in replicating these findings and examining how these changes are reflected in brain activity (by measuring electrical activity from the scalp, or EEG). The results may inform the future use of these interventions in clinical populations or treatment settings.

Why have I been invited to participate?
You are invited to take part if you are aged 18-35 years old and do not currently meditate or play lots of video games. So that our results are clear, all participants need to have normal hearing and vision (or corrected with glasses/lenses), speak English as a first language, have no previous neurological, serious physical, or mental health problems, or current use of psychoactive medications. In addition, participants must not regularly use illicit drugs, smoke cigarettes daily, or consume alcohol at harmful levels. Female participants must not currently be pregnant or breast-feeding. If you have used any illicit drugs in the past six months (e.g., cannabis, ecstasy), unfortunately you will not be eligible to participate. If this is the case, we ask that you do not complete the screening survey.

What will I be asked to do?
Firstly, you will be invited to complete a confidential screening questionnaire. This survey includes questions about your demographic information (e.g., age, sex, handedness, language), your experiences with video games and meditation, and some questions about your mental health and wellbeing, and the way that you typically respond or think. We also need to rule out other things which may affect brain activity, including neurological and physical conditions, some mental health conditions, heavy alcohol use, and use of some medications. All data collected will be kept in the strictest confidence as described below. Data from the screening questionnaire may also be used to examine the relationship between questionnaire variables related to trait mindfulness, wellbeing and personality.
If you are eligible to participate, the researchers will be in contact, and you can choose whether to participate in the study. The study will be conducted over two experimental sessions, 1 week apart, each taking approximately 2 hours. During each session, you will be fitted with an electrode cap for measuring your brain activity (EEG). You will then complete some computer-based tasks which relate to attention. In these tasks you will respond with a button press when particular word / symbols appear on the screen. During the week in between the two experimental sessions, you will be asked to practice meditation or relaxation techniques at home using a mobile phone 'app' (approximately 20 minutes per day for 7 days). The app will be paired with a headband which gives

feedback on current brain activity OR a handheld device which gives feedback on skin conductivity. You can choose to use the app on your own phone (if compatible) or you can borrow a compatible mobile phone from the researchers.

Are there any possible benefits from participation?
This research will contribute to scientific knowledge about whether training interventions (such as meditation or relaxation) can improve attention. However, we cannot guarantee that participation will enhance your attention or other cognitive abilities. This study may also inform the use of interventions in clinical samples or treatment settings in the future (e.g., anxiety, dyslexia, substance use, neurological rehabilitation, dementia, age-related cognitive decline). You will receive an $60 gift voucher to reimburse for time and out-of-pocket expenses. Alternatively, if you are an undergraduate psychology student, you can choose to receive four hours research participation credit and $20 reimbursement.

Are there any possible risks from participation?
Experimental sessions: The equipment used to measure brain activity may feel a little uncomfortable, however it is not painful and there are no specific risks associated with measuring EEG activity. If you have sensitive skin, there is a slight possibility of skin reaction from the electrode preparation materials. You are advised to reconsider participation if you have particularly reactive/sensitive skin. While EEG can be used for diagnostic purposes in medical settings, the researchers are not qualified in this area, and are not able to diagnose or provide information on any neurological conditions.

Training Devices: The training devices (brain sensing headband or hand-held skin conductivity device) used with the mobile phone 'apps' are low risk and comply with safety regulations. However, like most battery-operated electronic devices, there is a risk of harm if the devices are exposed to extremely high temperatures, low air pressures, or if they are crushed or tampered with. You will receive further information about these safety precautions during an introductory session at the end of the first experimental session.

Questionnaire measures: As described above, you will answer questions related to mental and physical health and alcohol use. If this makes you feel uncomfortable, or if you become distressed, you are free to discontinue the study at any time without providing a reason, and you may wish to contact one of the following free services. (Lifeline: 131114 or Beyondblue: 1300 22 4636), or you may wish to contact your GP.

What if I change my mind during or after the study?
Your participation in this study is entirely voluntary and there are no consequences if you decide not to participate. You are free to withdraw at any time during the study, without consequence, and you do not need to provide a reason. After the study, you may also choose to withdraw your data by contacting Allison Matthews (Allison.Matthews@utas.edu.au), at any time prior to 31st August 2019, after which time the results will be published.

What will happen to the information when this study is over?
All data will be treated in a confidential manner. Your data will be labelled using a unique code, rather than any identifying information. A data file which links this code to your name and contact details will be stored in a separate password protected file. Only the researchers involved in this study will have access to this file. All data will be kept on a secure computer server or in locked storage at the Discipline of Psychology, University of Tasmania. It will be stored for 15 years (as required for clinical trials), and then destroyed by secure deletion from the server, or by secure shredding.

How will the results of the study be published?

If the study is published, presented or communicated in other ways, the data will be reported as grouped data and no participant will be personally identifiable. If you would like to receive an email summary of the results, please email from Dr Matthews after January 2020, or a summary of results will be posted on the 'Utas Cog Neuro Lab' facebook page.

What if I have questions about this study?
If you would like more information about the research, please contact Dr Allison Matthews on 6226 7236 (or email Allison.Matthews@utas.edu.au), and feel free to ask the researchers any questions you may have before or after the experimental sessions.

This study has been approved by the Tasmanian Health and Medical Human Research Ethics Committee. If you have concerns or complaints about the conduct of this study, please contact the Executive Officer of the HREC (Tasmania) Network on +61 3 6226 6254 or email human.ethics@utas.edu.au. The Executive Officer is the person nominated to receive complaints from research participants. Ethics reference number: H0017994

This information sheet is for you to keep. If you would like to consent to being involved in this study, please sign the consent form provided.

Appendix G

Consent Form

Study title: The effects of Meditation and Relaxation on Neural Correlates of Attention: A Pilot Study

1. I agree to take part in the research study named above.
2. I have read and understood the Information Sheet for this study.
3. The nature and possible effects of the study have been explained to me.
4. I understand that the study involves:
    - Completion of an online screening survey
    - Attending two experimental sessions (of approximately two hours each) one week apart, during which my brain activity will be recorded while I complete some computer-based tasks, involving pressing buttons in response to words/symbols on a screen.
    - Practicing meditation or relaxation during the week in between the experimental sessions (approximately 20 mins per day for 7 days) using a mobile phone app and a device that measures either brain activity or skin conductivity.
5. I understand that participation in the experimental sessions involves a slight risk of skin irritation from EEG preparation materials if I have sensitive skin
6. I understand that there are safety precautions to consider when using or storing the battery-operated training devices (i.e., brain sensing headband or handheld skin conductivity device).
7. I have been provided with numbers which I can contact (see Information Sheet) if I have any concerns.
8. I understand that all research data will be securely stored on the University of Tasmania premises for 15 years from the publication of the results, and will then be securely destroyed.
9. Any of my questions have been answered to my satisfaction.
10. I understand that the researcher(s) will maintain confidentiality and that any information I supply to the researcher(s) will be used only for the purposes of the research.
11. I understand that the results of the study will be published as group data, and I will not be identified as a participant.
12. I understand that my participation is voluntary and that I may withdraw at any time without any effect and may request that my data be withdrawn from the research up until 31st August 2019.

Participant's name:

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Participant’s signature: ____ Date: _______________________

Statement by Investigator

☐ I have explained the project and the implications of participation in it to this volunteer and I believe that the consent is informed and that he/she understands the implications of participation

Investigator’s name: ____

Investigator’s signature: _________________________Date: _______________________

Appendix H

Mixed Models Main Effects and Interactions for Reaction Time

Table H

Mixed Model F Statistics for Reaction Time (ms)

Comparison	*df*	*F*	*p*
Group x Time x Condition	(2, 156)	0.62	.541
Group x Time	(1, 258)	0.01	.919
Group x Condition	(2, 156)	1.14	.258
Condition x Time	(2, 156)	1.83	.164
Time	(1, 158)	33.92	.000*
Group	(1, 33)	0.07	.798
Condition	(2, 156)	8.84	.000*

*indicates p<.05.